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CONTENTS OF VOL. XXXV.

PAGES

The Development of Electrical Science during the Nineteenth Century, and the Electromagnetic Theory of Light (Centenary Lecture). By Andrew Gray, LL.D., F.R.S., Professor of Natural Philosophy, University of Glasgow, 1-54

The Fiscal Policy. By Prof. William Smart, Phil.D., LL.D., 55-62

The Historical Development of the different systems of Education in the Highlands. By Professor Magnus Maclean, M.A., D.Sc., F.R.S.E., 63-81

Experiments in Radio-Activity. By H. Stanley Allen, M.A., B.Sc., 82-96

Some Developments in Chemical Theory during the Nineteenth Century (Centenary Lecture). By G. G. Henderson, M.A., D.Sc., F.I.C., Professor of Chemistry in The Glasgow and West of Scotland Technical College, 97-119

Some Observations on Primitive and Early Markets and Fairs. By Sir James D. Marwick, LL.D., F.R.S.E. 120-149

The Treatment of the Criminal and Offender. By James Devon, Medical Officer, H.M. Prison, Glasgow, 150-170

The Viscosity of Aqueous Solutions. By Charles E. Fawsitt, Ph.D., D.Sc., 171-175

Notes on Physical Apparatus. By H. Stanley Allen, M.A., B.Sc., 176-180

The Stability of Flying Machines. By W. E. Williams, B.Sc., 181-188

Advances in Chemical Industry during the Nineteenth Century (Centenary Lecture). By George T. Beilby, 189-217

PAGES

The Clear Facts of the Commercial Situation, and the Divergent Conclusions drawn from them. By W. J. Ashley, M.A., Professor of Commerce and Public Finance in the University of Birmingham, 218-230

Developments in the Means of Communication by Sea during the Nineteenth Century (Centenary Lecture). By Robert Caird, LL.D., 231-249

On Pseudogaylussite dredged from the Clyde at Cardross, and other recent additions to the Mineral Collection in the Kelvingrove Museum. By Peter Macnair, Keeper of the Natural History Collections in the Glasgow Museums, 250-262

Some Advances in Medical Science during the Nineteenth Century (Centenary Lecture). By Robert Muir, M.D., Professor of Pathology in Glasgow University, 263-288

The Future of Japan from the Geographical Point of View. By Sampachi Fukuzawa, B.Sc., 289-300

Age Incidence in Zymotic Diseases. By John Brownlee, M.A., M.D.(Glasg.), D.P.H.(Camb.), Physician Superintendent, City of Glasgow Fever Hospital, Belvidere, 301-310

Rules Governing the Competition for the Graham Medal, 311

Minutes of Session 1903-1904, 312-335

Office-Bearers of the Society, 336

Office-Bearers of the Sections, 337-338

Committees appointed by the Society, 339

Additions to the Library, 340-348

Exchanges with other Societies, 348-356

List of Periodicals, 357-359

List of Members, 360-378

Appendix (Constitution of the Society), 381-394

Index, 395

PLATES.

PLATE FACING PAGE
I.—The Progress of Electricity. Figs. 1-3, - - - - - - 8
II.—The Progress of Electricity. Figs. 1-3, - - - - - - 16
I.—Pseudogaylussite. Figs. 1, 2, 3, 4, Crystals of Pseudogaylussite, 254
Fig. 5, Nodule enclosing Pseudogaylussite and Marine Shells, - - - - - 254
II.—Pseudogaylussite. Fig. 1, Pseudogaylussite showing Spherulitic Calcite × 180, - - - - - - 254
Fig. 2, Pseudogaylussite showing layers of Calcite × 180, - - - - - - 254

DIAGRAMS.

DIAGRAM FACING PAGE
I.—Zymotic Diseases. The Normal Curve, - - - - - - 310
II.—Zymotic Diseases. Composite Curve of Whooping Cough, - - 310
III.—Zymotic Diseases, Mortality per cent. at each age period, - - 310

PROCEEDINGS
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ROYAL PHILOSOPHICAL SOCIETY
OF GLASGOW.

SESSION 1903-1904.

CENTENARY LECTURES, No. I.

The Development of Electrical Science during the Nineteenth Century, and the Electromagnetic Theory of Light.

By ANDREW GRAY, LL D., F.R.S., Professor of Natural Philosophy in the University of Glasgow.

[Prepared by request of the Council and delivered before the Society, 4th November, 1903].

It is a very remarkable fact that practically the whole of the modern science of electricity has grown up during the lifetime of the Royal Philosophical Society. Indeed much the greater part of it has been accumulated during the last sixty years, that is during the reign of Her late Majesty Queen Victoria. At the beginning of the nineteenth century the curve of scientific progress in electricity had begun to trend upwards, but comparatively very little had been done. The old classification of electrics and non-electrics, which practically represented the whole of electricity before the days of Stephen Gray, had been swept away by his discovery of electric conduction, and new and much more powerful means of developing electric effects had been discovered, with the result that a rough beginning of the quantitative study of frictional electricity had been made.

A notable figure at the latter end of the eighteenth century in electric work as well as in practical affairs was Benjamin Franklin, that remarkable compound of worldly wisdom, practical sagacity, and scientific instinct. Franklin had made great additions to our knowledge of electric phenomena. He had called down electricity from the thundercloud, and proved that a flash of lightning was merely a spark of electricity. He had put forward his one fluid theory of electricity which asserted that there were two things—electricity (of one kind only) and matter, that what was called a positive charge of electricity consisted in an excess and what we call a negative charge in a defect of electricity, and that matter attracted matter, and electricity repelled electricity and attracted matter. This theory in a modified form may throw some light on the very real difference that modern research has shown to exist between the phenomena of negative charge and discharge, and those of positive electrification. The work of Franklin deserves more careful study at the present time.

Towards the end of the eighteenth century Galvani and Volta had discovered electric currents produced by chemical action, Volta had given experimenters a means of producing electric currents of any strength when these were wanted, and it was possible to begin the real study of current electricity. No doubt experiments on currents had been made previous to Volta's time, for example, electrical discharges from leyden jars and condensers had been studied and their effects noted ; but it was now possible to cause electrical currents to flow for any required time, and to study at leisure their effects.

Volta's theory of the voltaic cell, which ascribes the flow of the current to the electromotive force produced by the contact of dissimilar substances in the circuit, has been much discussed of late years. Some modification of this theory is probably necessary; but in any case it must be supplemented by taking account of the changes which furnish the energy evolved in the circuit. That was done a good many years later when what may be called the energetics of the voltaic cell were discussed by Joule and others.

The most distinguished investigator in England at the beginning of the nineteenth century was the Honourable Henry Cavendish. A recluse and a misogynist, he shut himself up in his laboratory and occupied himself with electrical and chemical experiments from pure love of finding out the secrets of nature. He was careless of publication, and his results were for the most part jotted down on odd scraps of paper, backs of envelopes and so forth, and were only made known some twenty-five years ago when his Electrical Researches were published under the editorship of Clerk Maxwell. However, many of his discoveries were communicated at meetings of the Royal Society, and he became justly celebrated as a great chemist and a great authority in electricity. He worked at the distribution of electricity on closed conductors, and anticipated to a considerable extent the work of Faraday on this subject. No one who has learned

Natural Philosophy in this room, at any time during the last fifty years, is unacquainted with the proof which Cavendish gave of the law of inverse squares for electric attraction and repulsion—the proof based on the fact that there is no force within a closed electrified conductor provided there are no electrified conductors insulated in its interior. Then there was his work on the discharge of electrical condensers, in which he compared with marvellous accuracy the capacities of such condensers by the very primitive method of noting the sensations produced by passing the discharges through his own body. This method he also applied to the investigation of the discharge of electricity from electrical fishes. He studied the electrical organs of these creatures, and imitated their action by artificial torpedoes.

Another great investigator of the time was Coulomb in France. He determined by direct experiment with his torsion-balance (here is on the table an example of the instrument) the law of electric attraction and repulsion. By means of this instrument he was able to measure directly the actual force between two electrified conductors, and to make this measurement for different distances of the conductors apart, so that he was able to establish the proportionality of the force of attraction or repulsion, between two very small spherical electrified conductors, to the inverse square of the distance between their centres. Experimenting in a similar way on the forces between different magnets, he established the law of the inverse square also for magnetic attraction and repulsion.

Coulomb also invented the method of the proof plane for investigating the distribution on conductors. By placing a little thin disc of metal on the surface of a conductor, holding it by an insulating handle, he was able to remove a small portion of the electrical charge; and doing this for different parts of the conductor, and comparing the charges removed by testing them in his torsion balance, he was able to compare the amounts of electricity per unit area (the *electric densities*) on the surface at these different parts with one another. Thus he showed that the density was greatest where the surface of the conductor projected most or was most sharply pointed, while on hollows or depressions there was comparatively little charge.

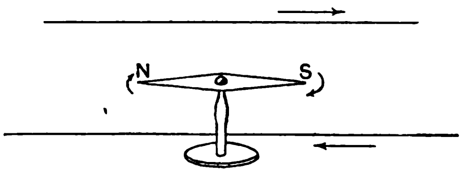
Coulomb also gave the law of electric force in the space just outside a charged conductor, a law which is of great importance in the mathematical theory of the subject. His results were used for the formation of a more extended theory of electrical distribution by the great French mathematician Laplace, who completely worked out the distribution on ellipsoidal surfaces. This laid the foundation for the brilliant work on the subject of electrical distribution on conductors carried out later by Poisson, Plana, Green, Thomson, and others.

In 1800, Nicolson and Carlisle discovered the electrical decomposition of water, and in 1807 Sir Humphrey Davy decomposed the alkalies by an electric current. Thus began the long series of researches in electro-chemistry which were continued by Davy and by Faraday, and since their time, by De la Rive, Becquerel, Beetz, Hittorf, and many others, and which have been the foundation in our time of a great branch of industry.

The career of Davy was a remarkable one. He came to the Royal Institution of Great Britain, then just founded by Count Rumford, to fill the post of Lecturer in Chemistry, and Director of the Chemical Laboratory. In Rumford's Life there is an interesting story of how the Count, who was a prudent and frugal New Englander like Benjamin Franklin, went out and bought some articles of furniture, including a folding bed which could be used as a sofa or armchair, to furnish Davy's living-room in the Institution, the whole costing only a few pounds. That was the beginning of Davy's nearly lifelong work in the Royal Institution, and he made many discoveries. He was a very great man; but notwithstanding the splendid work that he did, I do not hesitate to say that his greatest discovery was the discovery of Faraday. Faraday came to the Royal Institution in a humbler way than did Davy. He was a bookbinder's apprentice who attended the chemistry lectures, and having attracted Davy's attention was offered by him the post of attendant in the Chemical Laboratory. In a short time Faraday had become known as a discoverer in chemistry; and a little later still he began that series of brilliant discoveries in electricity and electromagnetism of which I shall by and by have to speak.

In 1820 came the great discovery by Oersted, of the action of an electric current on a magnet. The discovery had been proposed for discussion by the French Academy, and although the memoir of Oersted was not, so far as I know, put in competition for the prize, it certainly solved the problem.

With the apparatus before you I can repeat this experiment. Here is a horizontally suspended magnet; as you see it rests in the north and south direction, under the earth's magnetic force, being weighted so as to remain horizontal: I take this wire which is connected at its ends to the terminals of a voltaic cell, and stretch it in the north and south direction above the magnet. The magnet turns round, the north pointing end of the needle going towards you, the south pointing end towards me. I transfer the wire without other change of its position from above the needle to about the same distance below, and you see that the direction of turning is now reversed. If, however, keeping the wire still above the needle, and connected in the same way to the voltaic cell as before, I turn it end for end with respect to the needle, the needle turns in the opposite direction to that in which it turned at first; and a similar thing happens when I place the wire, turned end for end, below the needle. Therefore if I stretch the wire as at first along above the needle, and doubling it under here at the right, bring it back below, the two parts of the wire will



produce turning of the needle in the same direction, and the amount of turning will be greater than in either of the former cases. Therefore also, if, keeping the wire thus surrounding the needle as I have just described, I double it up at the left and bring it back again towards the right above, and carry it once more to the left below, and so on to any number of convolutions forming a coil round the magnet, I increase by each convolution the deflecting action of the current, and the needle is turned more and more nearly to the position perpendicular to that in which it is constrained to rest when acted on only by the magnetic force of the earth.

Reversal of the deflection could be produced also by keeping the coil of convolutions of wire fixed in position, and detaching the cell and reapplying it with the terminals connected oppositely to the ends of the coil. This is just the same as turning the coil round, keeping it connected to the cell. This reversal of the connection of the cell can be effected by an instrument called a reversing key, which, on the depression of one or the other of two levers, connects the terminals of the cell in one way or the other to the coil.

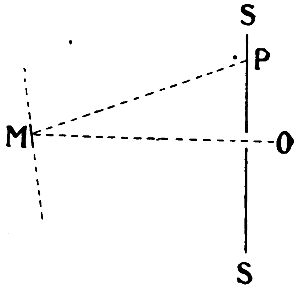
This turning action of the current in a conductor constituted Oersted's discovery, and it made telegraphy possible. For all that is necessary for the sending of signals is to have a coil connected with a cell or battery through a reversing key. Depression of the lever on one side sends the magnet round one way in the coil, and depression of the lever on the other side sends the magnet round in the opposite direction. Hence, if the key be at the station from which the signals are to be sent, and the needle be at the receiving station (and it is a question only of the delicacy of the apparatus, and of the battery power available, how far these stations may be apart), then a depression of the key on one side or the other by the sender of the message is made manifest by a deflection of the needle at the receiving station. Different agreed-upon sequences of deflections towards the same side or different sides of the coil, can be made to represent the various letters of the alphabet, and a message can be thus spelled out by the sender and read by the receiver of the message. This was the method of working of the old single needle telegraph, which was in constant use a good many years ago, and is in use still at some railway signalling offices. It formed the first great practical application of Oersted's discovery.

By coiling the convolutions round in a circular coil, making the needle very small and light, and hanging it by a single short fibre of silk[1] at the centre of the coil, and showing its deflections by a ray of light reflected from a small silvered mirror rigidly attached to the needle and turning with it, the delicacy of the instrument can be much increased. The coil and needle thus arranged can be made into an instrument by which what we may call the strengths of different currents of electricity can be compared, by means of the deflections of the ray of light; that is, as we call it, a galvanometer.

I have here on this stand such a galvanometer. A ray of light from this lamp at *O* in the Figure is thrown on the mirror *M*, and reflected from it to this scale *S*, *S*, of partly obscured glass which is hung as you see by two cords from the ceiling of the room. When a current is made to flow through the coil, the turning of the magnet is shown by the motion along the scale of the small luminous patch *P* on the glass produced by the incidence on it of the reflected ray of light. The reflected ray gives a long, and, this is a great point, massless index, turning with the mirror, and moreover turning through twice the angle that the magnet, and, therefore, also the mirror turns through. By lengthening the index, that is by increasing the distance of the scale, we can increase the sensibility of the arrangement.

---

[1] Or still better for exact measurements by one of Mr. C. V. Boys' extremely fine fibres of drawn quartz. For quantitative work a long and fine fibre is desirable. Quartz fibres are extremely strong, and can be drawn so extremely fine as to have practically no torsional effect.



I have described this arrangement at some length, but it is well worthy of careful attention, for it constitutes the instrument devised by Sir William Thomson for the reception of telegraphic signals sent through a submarine cable. It is not so much used for that purpose now, having been superseded, in great measure, by Lord Kelvin's other, and most beautiful instrument, the siphon-recorder. It is used, however, for the exact measurement of comparatively feeble electric currents in physical laboratories, and in different kinds of practical work, for example, the testing of submarine cables during manufacture or laying, or from time to time during their working life.

Immediately after Oersted's discovery, Faraday began his brilliant researches on electricity and electromagnetism. He made many experiments showing the action of currents on magnets. Oersted's experiment is, of course, an example of such action. I have a number of pieces of apparatus on the table here with which I shall illustrate different forms of this action. They are not all due to Faraday but they will illustrate his work.

Here I have a kind of star-wheel pivotted on its axis, (see Plate I., Fig. 1), and dipping at the extremity of its lower rays into a little basin of mercury. I am going to cause a current to flow from the axle of the wheel through the lower rays to the mercuryand back again round this wire circuit to the wheel. First I place a horse-shoe magnet thus, with its poles on opposite sides of the lower part of the wheel, so that what we call the magnetic field of the magnet is directed across the wheel from one pole of the magnet to the other, just where the current is passing along the metal rays from the axle to the mercury. The action of the magnetic field on a ray of the star-wheel in which the current is flowing is to move that ray across the field in one direction or the other according to the position of the magnet; for if the magnet is reversed in position relating to the wheel, the direction of the turning is also reversed. Thus the ray in contact with the mercury is forced forward, loses contact, and another ray comes into contact, the current flows in that, and it is moved the same way in its turn, and so on. Thus the wheel is kept in continuous rotation. We could repeat this experiment with a perfectly continuous disc, instead of a star-wheel: but it would be quite the same thing. In fact the disc may be regarded as a star-wheel with an infinitely large number of rays. The current in the disc would really be distributed in the whole disc but there would be a maximum density of flow at the lowest radius and zero density at the highest.

This apparatus is called Barlow's wheel, and it illustrates exceedingly well the fundamentally important fact that a current-carrying conductor placed in a magnetic field, so that it lies across the lines of magnetic force, acted on by a force causing it to cut across those lines. Think of it in this way. Let the stalks of corn in a field represent the lines of magnetic force (that is lines showing the direction in which a small magnet would set itself if acted on by the field alone), and let the knife-bar of a reaping machine represent the conductor carrying the current which flows along the bar from one end to the other: the action of the magnetic field on the current will be such as to move the bar forward or backward across the corn stalks. This action is greater the stronger the current, and the more intense the field—that is, in a sense, the more numerous the stalks of corn.

Now let me, anticipating a little, say a word or two regarding a kind of inversion of this action which is of the very greatest importance. Suppose no cell or other current generator in the circuit, and, therefore, no current flowing in the star-wheel, but everything else as before. Suppose then I closed the circuit—here are the wires—nothing would happen, there would be no motion of the wheel. But now suppose that while the circuit is closed through the rays of the wheel dipping into the mercury the small wheel is turned round by a motor geared to its axle, or by some one turning a handle, a current would be made to flow in the

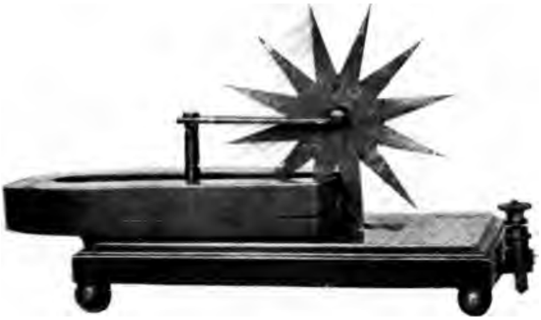


Fig. 1.

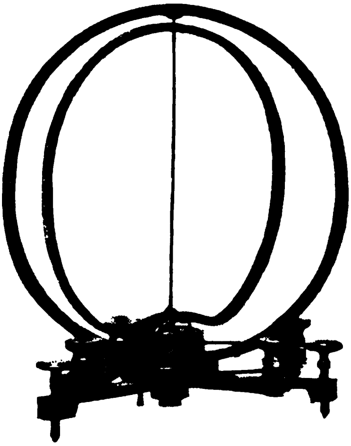


Fig. 2.

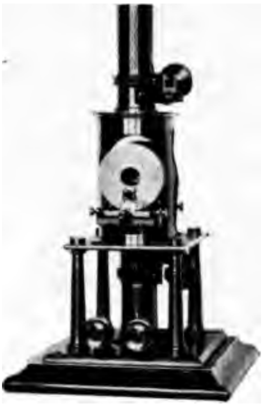
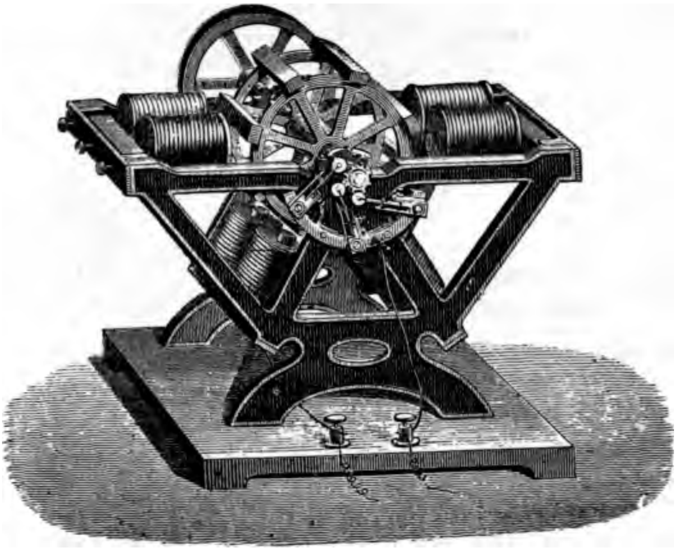


Fig. 3.

circuit. We should have a magneto-electric machine. This inversion of the action of the Barlow wheel was pointed out by Faraday, and was an obvious outcome of his theory of the induction of currents.

I shall take now this little electromagnetic engine, which is a form of electric motor invented a long time ago by Froment, a French experimenter. We have two sets of electromagnets here, pieces of soft iron which are made magnets by the passage of currents through coils of wire surrounding them, which is in itself a remarkable fact to which I ought in its proper place to have made special reference. These electromagnets, as we call them, are arranged in pairs with opposite poles pointing in the same direction outside this little wheel. Across the rim of the wheel are attached a number of small bars of soft iron, or armatures, as they are called. When the wheel is set rotating and one of these pieces of iron approaches the extremities of a pair of electromagnets it becomes a magnet in virtue of magnetic induction, and it is attracted by the electromagnet, and is therefore made to move towards the latter with increasing speed. When it is passing the electromagnet it is moving at its greatest speed and therefore passes on. At the instant of passing the current circulating in the electromagnet is reduced to zero by a



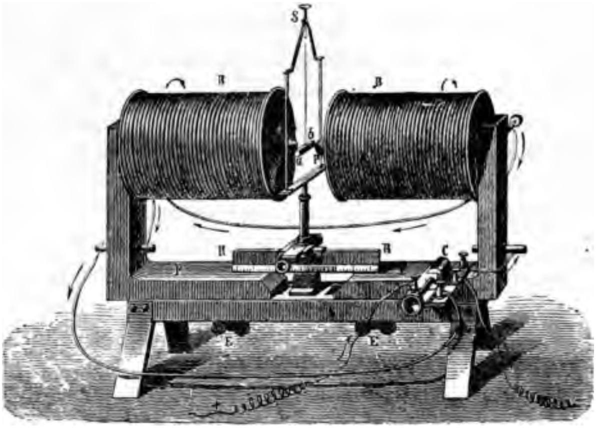
contact making and breaking contrivance which cuts off connection with the current supplying battery. The armature is thus released from the action of the electromagnet, which after the passage would have tended to stop the motion. When another armature has come within 15° or 20° of an electromagnet, the current is again set flowing, and the armature is attracted, and the motion accelerated as before, until the current is once more cut off when the armature is just opposite, and so on as the armatures approach in succession. The four pairs of electromagnets all act in the same way, and they are so placed that something approaching to equable continuous action is given by the combination.

This other little engine is exceeding interesting, as it is a form of motor invented, I believe, by Dr Joule. Two semicircular magnets are arranged so as to form a vertical circle, or rather a circular magnet, with opposite poles at the extremities of a horizontal diameter. Mounted on a vertical pivot at its centre and at the centre of the circle is a bar electromagnet. When it is set revolving without, let us suppose, any current in its coils, a contact-making arrangement, brought into action by the revolution, sets a current flowing, which gives magnetic poles to the coils and their cores opposite to the poles of the circular magnet to which the outer extremities of the coils are approaching. The motion is therefore accelerated, and continues without retardation after the coils have passed the plane of the circle, since just at the moment of passage across this plane the current in the electromagnet is cut off.

In this other arrangement, (see Plate I., Fig. 2), the action takes place without any magnetisation of iron, in virtue entirely of the action between two coils of wire in which currents are flowing. The current is started and stopped in the coils as before, so that there is little or no retarding action, and the motion is kept up.

I have mentioned the fact that a current flowing in a coil of wire surrounding a soft iron core magnetised the core. This discovery was made by Arago in France, in 1820. Here is a special arrangement of a coil and core to illustrate it. When the core is held above this pile of nails, and the coil is connected to the battery of cells, you see that the nails are lifted, and that when I break the connection the nails are dropped. You will observe that the nails are held quite a sensible interval of time after the withdrawal of the connection with the battery, which shows that the iron core and the nails—for every nail becomes a magnet for the nonce—lose their magnetism at once when the current is stopped.

Before you on the table here is the form of electromagnet made for experimental purposes by Ruhmkorff, and regarded in its day as a very effective instrument; and here, arranged to show a celebrated experiment of Faraday's, is a very much more powerful electromagnet which has recently been built for the Physical Laboratory by Messrs. Mavor and Coulson, (see Plate II., Fig. 3).



The experiments of Oersted, and others of like character which were devised when Oersted's discovery became known, received their explanation in a very remarkable memoir on the action between currents and magnets, and between currents and currents by the French mathematician Ampère, who has been appropriately called the Newton of Electricity.

Ampère gave a mathematical theory of these actions which united the various diverse effects very much as Newton's theory of gravitation united the various observations of Tycho Brahe and Kepler. The foundation of his theory was the important principle that a wire carrying a current of electricity is equivalent to a certain corresponding distribution of magnetism, a certain arrangement of small magnets, and that all the actions between magnets and currents, or between currents and currents, are simply actions between different distributions of magnetism. Ampère's theory gave a great impetus to scientific discovery. It rendered definite the scientific ideas of investigators, and prepared the way for the great discovery of the Induction of Currents, which came only about five years later.

This is the proper point at which to refer to the important work of G. S. Ohm, which consisted in the application to the flow of electricity of the ideas and theory put forward by Fourier in connection with the flow of heat. Everybody has heard of Ohm's law, yet it is rarely correctly stated. Consider a metallic wire, of copper say, which is all at one temperature, and is not in motion in a magnetic field. Let it be connected with a voltaic battery, so that a current flows in the wire, and let the current have a *steady* value, that is one which does not change as the time proceeds. What we call a difference of electric potential exists between two points in the wire, one near one end and one near the other end. Ohm's law asserts that if the temperature of the wire is kept unchanged, the current flowing in the wire, as properly measured by a galvanometer, is directly proportional to the difference of potential (or, as it is called sometimes, the potential slope along the wire) just referred to.

The law as thus stated for a homogeneous conductor carrying a steady current can be extended to the different homogeneous parts of which the heterogenous circuit is made up. In each part the current (which is the same at any instant in all parts) varies with the fall of potential in that part, and the sum of the falls in the different parts is what is called the electromotive force of the cell. Thus we get the proportionality of the current in the circuit to the electromotive force of the battery.

From this comes the idea of the resistance of a conductor to the flow of an electric current through it. This is not a resisting force to the passage of something material. The resistance of the homogeneous conductor (referred to above) between the two points near its ends, is the ratio of the difference of potential between those two points to the current flowing through the conductor. The constancy of this ratio under certain conditions is the physical fact asserted in Ohm's law. Similarly the total resistance of a battery circuit is the ratio of the electromotive force of the battery to the current flowing.

Faraday's researches in induction began in 1831. One of his earliest experiments consisted in bringing into the field, as we call it, of a powerful permanent magnet, a bar of soft iron round which had been wrapped a coil of copper wire, the different turns of which were insulated from one another by a covering of silk. The ends of the coil were not quite in contact, but were separated by a little gap. Thus, when the bar was brought into the field, or removed from it, a spark was seen to pass across the air gap, showing that the magnetisation of the iron, or its demagnetisation, made a current flow in the coil surrounding it.

What takes place can be more fully studied by means of this other experiment, which is also one devised by Faraday. Here are two coils of wire, merely two hanks of ordinary cotton covered wire hanging side by side, (see Plate II., Fig. 2). I send a current of electricity from a voltaic cell through one of these coils by depressing this key. A current is started in the coil, but it does not take its final value all at once. There is a short but quite perceptible interval of time, during which the current is rising from nothing to its final value. Now, while the current is so rising to its final value, there is an action on the adjacent coil which is hanging side by side with the first, an action which produces a current of electricity in it also, but in the *opposite* direction. Similarly, when the key is raised and the current thereby stopped in the first coil, the current does not fall from its steady value to zero all at once, but takes a sensible interval of time to do so. While the current is thus growing weaker, towards zero, in the first coil, there is again an action on the second coil producing a current in it, and in the *same* direction as that in the first coil. The two actions on the second coil, that due to the rising current and that due to the falling current in the first, are perfectly similar, but the currents produced are in opposite directions.

I now depress the key: the current begins to flow in the first coil, and a transient current flows in the second, and makes its existence visible by the deflection of the needle of this galvanometer, the coil of which is included in the circuit. You see the spot of light reflected from the mirror carried by the needle move towards your left, and then come back to its original undeflected position. This shows that as the key is kept depressed, and the current in the first or primary coil, as I may call it, is started, and allowed to rise to its final or steady value, the current in the other or secondary coil begins, rises to a maximum, and then dies away to nothing.

The key has been kept down until now: I raise it. The current in the first coil falls rapidly to zero as its current is broken, and a transient current in the opposite direction flows in the second coil, as you see by the momentary deflection of the spot of light towards the right.

Observe here that the circuit cannot be broken with absolute suddenness. For one thing, the contact of two pieces of metal is not, as you are apt to regard it, the contact of two definite polished surfaces, which are either in contact or not. The pieces of metal are, in point of fact, assemblages of molecules, which interpenetrate one another more or less where the contact takes place. The amount of this interpenetration shades off from its greatest to zero as the contact is annulled, that is, the annulment of the contact is a gradual process. Again, the current can be carried across a thin layer of air, even after the contact has in a very true sense ceased to exist, and thus the flow is prevented from quite suddenly stopping.

In point of fact, there is something very much akin to the inertia of matter about the flow of the current. Draw a pendulum which is hanging in the vertical to one side, and let it go. It swings back towards the vertical, but it does not stop there. As it moves towards the vertical its speed continually increases, and therefore when it has arrived at the vertical the bob is moving at its fastest. Its inertia carries it beyond the vertical, and it is only stopped after the retarding force, which comes into play when it begins to climb up on the other side of the vertical, has had time to stop it.

In the same kind of way, time, and the continued action of what in the electrical case takes the place of the ordinary dynamical force on the pendulum bob, are required for the stoppage of the electrical flow, a fact which, when we come to the phenomena of oscillatory discharge, will acquire for us perhaps a clearer significance.

The currents we have observed are what are called *induced currents.* One is called the induced current at "make" of the primary circuit, the other the induced current at "break."

The effects produced by starting and stopping the current in the primary might equally well have been produced by quickly bringing the primary current, with the current already established in it, from a distance up to close parallelism with the secondary, and then quickly withdrawing it. The approach of the primary would give a similar induced current to that excited at the "make" of the circuit, the withdrawal a similar current to that induced at the break.

Further, the primary circuit in this latter method of producing the currents in the secondary may be replaced by a magnet. Thus, if I do away with the primary and bring this ordinary bar magnet up towards the secondary so that one end of it points towards the coil, a deflection of the spot of light takes place in one direction, and when I withdraw the magnet a similar deflection takes place, but in the opposite direction, (see Plate II., Fig. 1). Approach or withdrawal of the magnet is equivalent to approach or withdrawal of the primary coil with the current in it. This, of course, illustrates and confirms Ampère's view that a circuit carrying a current is, in point of fact, a magnet. The same view is further confirmed by the fact that if the primary have a soft iron core, so that it forms an electromagnet, in the ordinary sense of the word (all circuits with currents in them are electromagnets), the inductive effect on the secondary is much more powerful.

Now let us look at a theory of these actions which we owe to Faraday, and which is very naturally suggested by the two forms of the experiments last described, a theory moreover which furnishes the foundation of the mathematical theory of current induction at the present time, and therefore constitutes one of the great landmarks of electrical progress. Faraday thought of the current when it was made to flow in the primary, as setting up through that coil a system of what he called lines of force, or, as they are now more frequently called, lines of induction, which also pass through the secondary, since that is parallel and near. Similarly, when a magnet is brought up to the secondary, it brings with it the system of lines of force which Faraday regarded as existing in the space about it—its magnetic field as we call it—and these lines are thrust through the secondary. The two processes are essentially the same. When the primary has a current started in it its lines of magnetic force are called into existence, and are thrust through the secondary. When the coil with the current in it is brought up, the lines previously existing are brought with it, and inserted into the secondary. Similarly, when the current is stopped or the primary coil is withdrawn, the lines are withdrawn from the secondary. All this is precisely what happens when the magnet is used instead of the primary coil and current. As can be proved in various ways, the total or integral effect as measured by the whole quantity of electricity which flows in the induced current is independent of the length of the interval of time occupied in bringing up or removing the inductive circuit, or in placing in position or withdrawing the magnet.

The lines represent and typify a certain change of physical state of the medium produced by the presence of the current or magnet. This state is in a certain sense circuital round the conductor in the manner represented by the closed curves in the diagram [not here reproduced]. It is their insertion into or withdrawal from the secondary which produces the currents. The greater the rate at which lines are being inserted, the greater is the action producing the current. In other words, the electromotive force, as we call it, in the secondary at any instant, is proportional to the number of lines being sent through the circuit, or withdrawn from it, per unit of time. The quantitative conclusion just stated may be confirmed by many simple experiments by means of magnets. For example, we may keep the magnet stationary, and in its magnetic field displace the secondary circuit, and we can mould or shape a portion of the circuit so that any part of it we please may be affected by inductive action. Thus, let us turn a part of the circuit into a small coil of say three turns, and then suddenly place the coil between the poles of this horse shoe magnet, so that the lines of force which pass from one pole to the other, also pass through the three turns. A certain inductive effect is produced, which is measured by the whole quantity of electricity which flows round the circuit; and an equal effect, but opposite in direction, is produced when the coil is withdrawn from the magnet. Now, let us remove one turn of the three and repeat the experiments. A smaller effect—one, in fact, two-thirds of the former—is produced, and this will be halved if we reduce the small coil to one turn.

This theory is well illustrated by an arrangement used by Faraday, and shown on pages 43 and 44. The primary and secondary circuits are wound on opposite halves of a ring of iron. In this all the lines of force were confined to the iron; those produced by the primary current passed round the ring through the secondary, and were withdrawn when the primary current was broken. The actual ring with its coils is shown also in this cut. Clearly it was almost exactly one of the modern forms of "transformer."

I have not time to go into further details as to how the "number of lines" passing through a circuit is to be specified or measured. Suffice it to say that there is a very definite sense

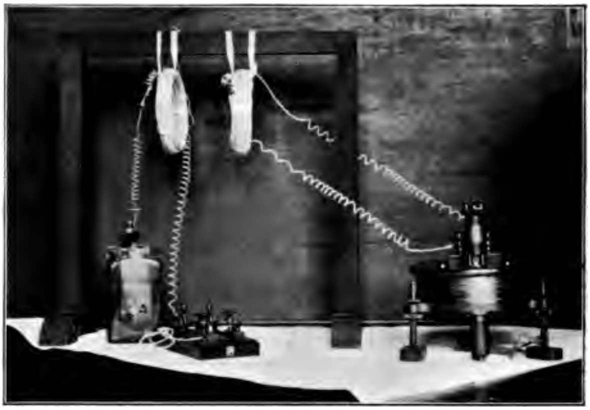


Fig. 1.

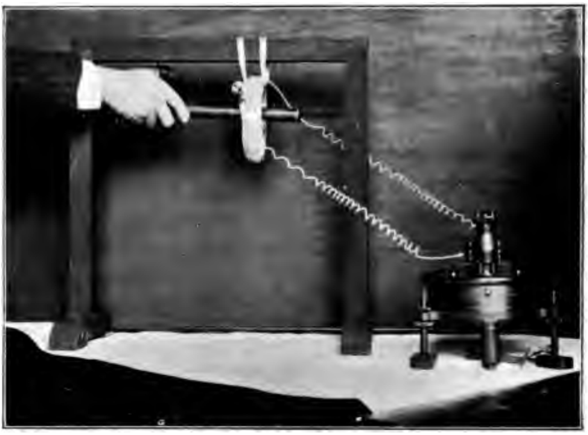


Fig. 2.

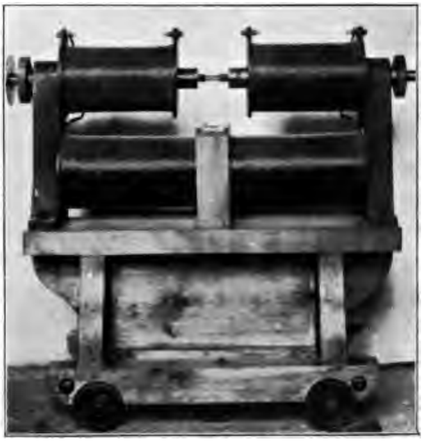


Fig. 3.

ascribed to this quantity, which lends itself to theoretical and experimental discussion.

I must notice here also the law of Lenz, according to which the current produced by induction opposes, so to speak, its own creation. For example, we might suppose the induced current to be caused by the approach or withdrawal of the primary circuit. The induced current in the secondary is then such as by its electromagnetic action on the secondary to oppose the motion of the primary—approach or withdrawal—which produces it. This is directly related to the fact that if the current in the secondary is induced by the rise or fall of the primary current, while the primary circuit is stationary, the lines of force called into existence, or annulled, simultaneously with the secondary current, are such as to set up by their insertion into the primary circuit, or withdrawal from it, an electromotive force in that circuit opposing the rise or the fall, as the case may be, of its current.

This law led to the treatment of a system of circuits or of circuits and magnets as a dynamical system, and thereby brought the whole subject of electromagnetism and electromotive action into line with dynamical science, as a dynamical theory of transformation of electric energy.

Lenz's law is also illustrated by the experiment, due to Arago, of hanging a copper disc over a horizontal bar magnet which is then rapidly rotated about a vertical axis. Currents are induced in the disc by the motion of the magnet, and the electromagnetic action between these currents and the magnet tends on the one hand to stop the magnet, and on the other to pull round the disc after the magnet. This is seen by the turning of the disc in its own plane about the suspension thread. Or the disc can be driven round in its own plane beneath the magnet suspended above it. The relative motion, as before, induces currents in the disc; but now the action on the magnet is shown by the fact that the magnet follows the disc.

A very striking form of the same experiment is that in which a coin is suspended by a twisted string, so that it hangs in the space between the poles of a horizontal electromagnet. If the magnet is unexcited the coin will, as the string untwists, be whirled about a vertical axis; but as soon as the current is turned on, and the magnetic field is brought into existence, the coin stops at once almost entirely, and the untwisting fails then to turn it except very slowly. This result is due to the action between the induced currents in the coin and the field.

Or if a metal disc, like that of the Barlow wheel (but without a wire circuit), be turned about a horizontal axis, so that it cuts across the lines of force of the electromagnet, work must be spent to keep it moving, and the work done is found to be spent in heat in the disc.

It will now be clear to you that if we have only the primary coil itself, we may regard it as its own secondary; the insertion of the lines of force into it by the starting of a current in it will produce an electromotive force in the primary, opposing the growth of the current. Similarly, the withdrawal of lines of force from the primary, owing to cessation or diminution of the current in it, will produce an electromotive force in the primary itself, tending to enhance the decaying current. This is what Faraday called the electromotive force of self-induction.

I shall try to illustrate self-induction by means of this electromagnet. I have connected a small glow lamp and a battery between the terminals of the magnet, in such a way that there are two paths for the current from the battery, one through the magnet coils, and the other through the glow lamp. You see that the part of the battery current through the lamp produces only a very faint glow in the lamp filament. The other part of the current has magnetised the iron cores of the magnet, and thus through the magnet coils there passes a very large number of lines of magnetic induction, or *lines of force*, as they are very commonly called. When the circuit of the magnet coils is broken, these lines are withdrawn from the circuit, and there is produced in consequence a very considerable though transient electromotive force, which causes a current sufficiently strong to make the lamp glow brightly to flow through its flament. The magnet is now made by the current from this small secondary battery. I break its circuit and you see the lamp flash out brightly for a moment.

These experiments so far as they go, illustrate the discoveries of Faraday. But, as he showed himself, and illustrated by experiment, his theory shows us how to obtain by inductive action, not merely transient currents, but currents which, however they may vary, continue for finite intervals of time; and these of course are the currents which are of most practical importance in applications of electricity. If we could arrange to have the number of lines of force passing through a circuit made to vary continually, we should have a current, possibly of varying amount, but flowing so long as the variation of lines of force lasted. I have already referred to this in describing Barlow's wheel. In that instrument a conductor—the lower part of the wheel—is moved across the lines of force of a magnetic field, and in a sense the number of lines cut by the revolving conductor per second is the rate at which lines of force are being added to the circuit of the disc and attached wire, and is the measure of the electromotive force. It will be observed that in that arrangement the circuit remains invariable in the magnetic field, and the total number of lines of force through it remains constant. The fact is that in the part of the wheel moving away from contact with the mercury, the current gradually ceases, and in the part coming into contact with the mercury the current begins to flow more strongly. From the partial cessation of the current in the leaving part of the disc arises an electromotive force which aids the current in the circuit, and from the growth of the current in the arriving part of the disc there arises an electromotive force which opposes the current in the circuit, and these just balance one another, leaving the cutting of the lines of force to have its full effect. Thus we may regard the number of lines of force through the circuit, that is as we sometimes more precisely put it, the total *magnetic induction* through the circuit is effectively increased at the rate at which lines are cut across.

This, the simplest form of magneto-electric machine for the generation of currents, was suggested by Faraday, and in various forms has been realised as a more or less practical generator by several inventors in recent times.

On the development of magneto-electric machines and the discovery of the self-exciting dynamo, I shall have one or two brief remarks to make later ; but the history of the dynamo during the last twenty or thirty years is really the history of the application of electricity to electric lighting and engineering, and is subject matter for a lecture or even a course of lectures in itself.

Here I ought to refer to the epoch-making work of Joule on the energetics of voltaic circuits. His name is generally associated with the determination of the dynamical equivalent of heat; but his quantitative examination of the mode in which the energy lost from the battery is disposed of in the circuit, is the basis at the present day of the theory of generation and transmission of power by electricity. He showed that if a current, of strength C as measured properly by a galvanometer, flowed through a wire of resistance *R*, the rate of evolution of heat was proportional to the square, or second power, of *C*, and directly proportional to *R*.

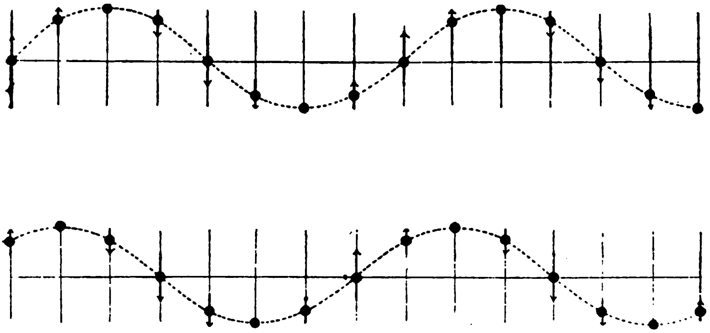
Moreover he showed that if magnets were moved, or a motor (or, as he called it, an electromagnetic engine) were driven by the current, the amount of heat evolved for a given amount of chemical change in the battery, was less than it would have been by the quantity of work done on the magnets or motor. He established, in fact, the law of conservation of energy for electric currents, an achievement in my opinion no whit less than its verification for heat developed by the friction of fluids.

Joule also, I may mention here, made one of the first absolute galvanometers and showed how to use it; he also constructed electromagnets of large pole-surface and great power, and experimented on voltaic cells of different kinds. An expert electrician would learn much at the present time by the perusal of his collected papers.

In the course of his electrical researches Faraday from time to time returned to a problem which had fascinated him, the question of a relation between magnetism and light. After many fruitless attempts he, as he says in the *Philosophical Transactions*, in a paper read November 20, 1845, "at last succeeded in magnetising and electrifying a ray of light, and in illuminating a magnetic line of force." I can best describe his discovery by repeating his experiment. Though the apparatus I shall use differs in various details from that employed by Faraday, it is in all essential particulars the same.

I have here the large electromagnet, to which I have already referred (see Plate II., Fig. 3), and which produces an intense field in the space (*A B*) between the ends of its iron cores. The lines of force run across from the core-end *A* to the other *B*. The iron-cores are perforated lengthwise along their axes, and a ray of light can be sent through from one end of the apparatus to the other. Therefore such a ray passes along the lines of force of the field of the magnet, if the field exists. Now, Faraday's discovery was, that if a ray is thus sent, and is plane polarised before entering the field, it will, in passing through the field, have its plane of polarisation turned round through an angle depending on the field-intensity and on the distance traversed in the field by the light. The diagram here given (p. 23) shows a slightly different arrangement with a horseshoe electromagnet. It shows also the polarising and analysing prisms, *P*, *A*, referred to below.

A word or two as to the meaning of plane polarised light may be desirable. You may figure to yourselves the particles of the medium which is the vehicle of light as displaced from a straight line arrangement along the direction of propagation, and moving each in a line transverse to that direction, in the manner represented in this diagram.[1] The second figure of the diagram shows the positions of the particles after a certain time has elapsed, and you see that in that interval the configuration of the particles has moved from right to left through a certain distance. A wave of plane polarised light then may be regarded as typified by this diagram; the particles all move in parallel transverse lines, and as a consequence, the arrangement or configuration moves on with a velocity which we call the velocity of propagation. Such a beam may be produced by the arrangement called a Nicol's prism, which splits a beam of ordinary light into two for which the vibrations are in planes at right angles to one another, and reflects one of these out of the line of propagation of the main beam, leaving the other to proceed. The plane of vibration is parallel to what is called the principal plane of the prism. If the light is received by a second prism, this must, if the light received is not to be extinguished, but is to be allowed to pass, have also its principal plane parallel to the direction of vibration. The position of this principal plane there tells us



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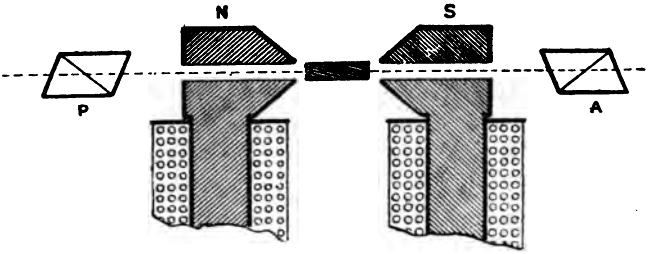
[1] It may be, and probably is, the fact that this transverse motion of a material medium, is not the real phenomenon. It must, however, have a certain correspondence to what actually takes place, and will serve for illustration.

what is the direction of vibration of the particles in the light received by the second prism.

Now imagine two such prisms (*P*, *A*, of the diagram on p. 23), one by which the entering light is polarised, the other by which the emergent light is received, and so to speak tested and analysed. If the principal planes of the two prisms be parallel, a beam of plane polarised light produced by one and received by the other, will, if the plane of polarisation is not changed by the medium between the prisms, be allowed to pass by the latter; if however the principal planes be inclined to one another at an angle less than 90°, an amount of light dependent on that angle will will be passed by the second, and if the angle between the prisms be 90° no light at all will pass through the second. The action of the prisms is analogous to that of the slits in the diagram. When the slits are parallel a wave of vibration in their plane is not interfered with. But when one is turned round through 90° from parallelism, a wave of transverse vibration passed by one will be stopped by the other. If they are not at right angles a component of a wave wholly passed by one will be allowed to pass by the second.

We have thus an obvious test of change of the position of the plane of polarisation by the medium between the prisms, or by a change in that medium. It is only necessary to send the beam through and adjust the second prism for extinction of the light; then to produce the change in the medium, and observe whether the light is now transmitted through the second prism. If any change in the plane of vibration of the light is set up, the beam on reaching the second prism will be resolved into two by it, one of which will be transmitted. If the light sent through be white light the amounts of the different constituents transmitted will be different, and the light transmitted will have a corresponding tinge of colour.

Now here between the poles of our electromagnet, which is as yet unexcited, I have placed a rod of Faraday's "heavy glass" (a kind of borate of lead), about ten centimetres long. The light sent along the cores, and therefore along the direction of the lines of force called into existence when the magnet is excited, passes through the rod from end to end. I pass the light through, and you see that the light which emerges from the farther prism produces a spot of light on the screen before you. I turn the second prism round its axis (that is round the direction of the light), and you see that the spot grows brighter, then grows fainter until it disappears, then appears again, grows brighter to a maximum, then again wanes and disappears. Finally I adjust the second prism for extinction, and then turn the current on the magnet which up till now has remained unexcited. You see that the spot of light on the screen reappears when the magnetic field is produced in the piece of heavy glass. I break the circuit and the spot again disappears. You may notice also that during a short interval of time, the spot gradually grows in brightness after the current is started, and gradually falls off in brightness to disappearance when the current is stopped. This is due to the fact that the magnetism in the iron cores can neither be produced nor removed with perfect suddenness. A change is produced in the medium, the production or removal of which is resisted by something like inertia.



We may perhaps make the effect better visible by arranging for a slight passage of light, with the analysing prism so placed that the production of the magnetic field causes more light to pass, and therefore brings about a brightening of the spot of light.

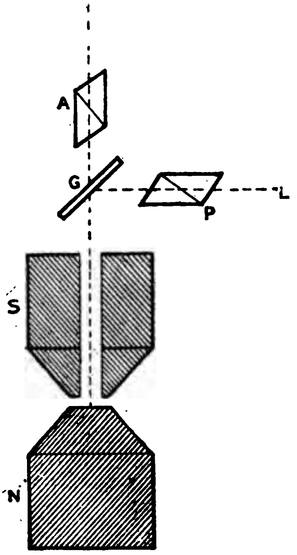
This effect is Faraday's discovery, and it is one of the greatest interest and importance, both practically and theoretically. The amount and direction of turning of the plane of polarisation depends on the substance occupying the field. It has a slight but distinct value in air and other gases, a much greater value in heavy glass and bisulphide of carbon, and an enormous value in a film of iron so thin as to be transparent to light. Heavy glass and bisulphide of carbon are what are called diamagnetic media, that is, the magnetisation produced in them by a magnetic field is opposite in polarity to that which would be produced by the same magnetic field in a piece of iron, or any other *paramagnetic* substance. It is not the case, however, that the direction of rotation is opposed in paramagnetics to the direction in diamagnetics;

among both classes of substances there are some which rotate the plane of polarisation in one direction, and some which rotate it in the opposite. For example, in heavy glass, bisulphide of carbon, cobalt, nickel, and iron, the turning is in the direction in which the current circulates in the coils producing the field.

It is found, moreover, that the amount of turning is proportional to the field intensity in the case of the slightly magnetisable substances, and proportional to the magnetisation in the case of the magnetisable metals. This fact enables a column of heavy glass, or bisulphide of carbon, to be used as a measurer of field-intensity when that is very great. The amount of turning produced per unit of length of the column, and per unit of field-strength, is known, and so from the observed turning the field-strength is obtained.

Since Faraday's time the dependence of the amount of turning on the wave-length has been investigated, and the effect has been observed in a large number of substances; but the most remarkable results to which the discovery has led has been the light which Lord Kelvin has made it throw upon the nature of magnetisation.

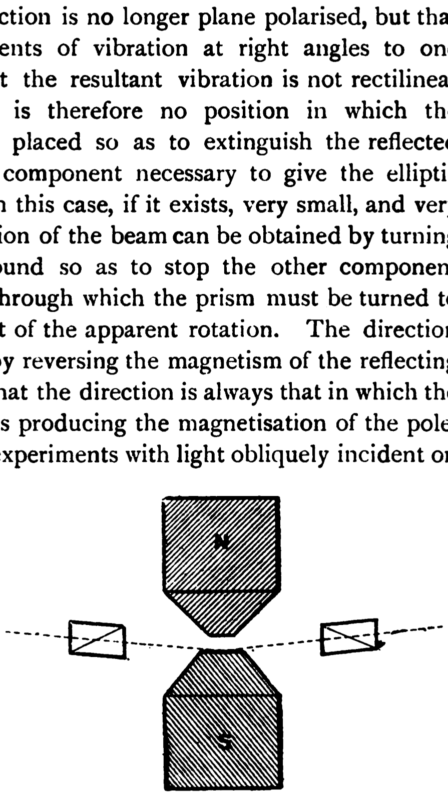
Before I pass on to that however let me call attention to some remarkable discoveries in this subject made by Dr John Kerr of Glasgow. Here is an electro-magnet arranged as in this diagram. The light from the lamp at *L* is first plane polarised by the Nicol *P*, then it is thrown on the piece of silvered glass *G*, and part of it is thereby reflected through this perforated pole-piece so as to fall normally on the polished point of the other pole-piece. Reflection thus takes place at perpendicular incidence, and the reflected light is received by this second Nicol. When the magnet is unexcited the second Nicol is arranged so as to quench the reflected light. The magnet is then excited, and it is found that the light is faintly restored, showing that an effect on the polarisation of the light has been produced by the magnetisation. It is to be noticed here



that the beam of incident and reflected light travels along the direction of magnetisation. We shall not pause to make this experiment. The effect is slight, and might not be noticeable without precautions, which we have hardly time to make, to exclude all extraneous light from the screen.

It would perhaps be incorrect to say that the plane of polarisation has been rotated in this case, as it has been asserted by Righi that the light after reflection is no longer plane polarised, but that there are two components of vibration at right angles to one another, so related that the resultant vibration is not rectilinear but elliptical. There is therefore no position in which the analysing prism can be placed so as to extinguish the reflected light. The transverse component necessary to give the elliptic vibration is, however, in this case, if it exists, very small, and very nearly complete extinction of the beam can be obtained by turning the analysing prism round so as to stop the other component vibration. The angle through which the prism must be turned to effect this is the amount of the apparent rotation. The direction of rotation is reversed by reversing the magnetism of the reflecting pole. Dr Kerr found that the direction is always that in which the current flows in the coils producing the magnetisation of the pole.

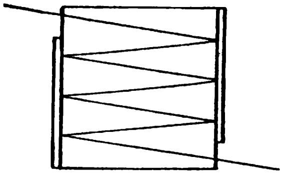
Dr Kerr also made experiments with light obliquely incident on a pole-face, with the arrangement of apparatus shown in this other diagram. He found that the previously plane polarised light was by the reflection rendered slightly elliptically polarised. A slight turning of the analysing Nicol was necessary to place it so as to stop the vibration corresponding to the long axis of the ellipse and so secure imperfect extinction.



These effects are, like those of normal incidence, very small, and they can hardly be shown to an audience.

Of another effect discovered also by Dr Kerr, double refraction in glass subjected to electrostatic strain, I have now no time to speak. The discovery is however of great interest and importance.

Most of those present know that rotation of the plane of polarisation of light is produced in substances like solutions of sugar and of tartaric acid, crystals of quartz, and so forth, and this *natural turning*, as the Germans call it, of the plane of polarisation has often been confused with the magnetic turning discovered by Faraday. But there is one great difference between the two phenomena, which points to their entirely different origins. If a beam of light transmitted through a slice of quartz crystal, cut at right angles to the axis, be reflected and sent back through the crystal, the turning of the plane of polarisation which takes place in the direct passage is undone in the reverse. On the contrary, if the beam sent through a column of heavy glass, or across a film of iron placed at right angles to the lines of force of a magnetic field, is reflected back and forwards as shown in this diagram, along the lines of force, the turning produced in each reverse passage is in the same direction as that already caused by each direct passage in the field, and of the same amount. Whether the light pass along the lines in the sense of the force or in the opposite sense, the plane of polarisation in these substances, as the beam progresses, is turned more and more in the direction of the current producing the field, so that the directions of the lines of vibration form a twisted surface like that sometimes seen on the under sides of the steps of a turning stair.



It was pointed out by Lord Kelvin that this difference of behaviour in the reflected beam in the two cases could be explained by supposing the turning in quartz or sugar to be due to the structure of the transparent medium transmitting the light, and the turning in the magnetic field to be produced by rotational motion of the molecules of the magnetised substance, which must be compounded with that motion of the medium in which the light propagation consists. On this view the difference between a magnetised body and an unmagnetised one, would lie in the fact that in the former there exist a large number of small rotating particles with their axis of rotation, on the whole, in a state of alignment along the lines of force, and rotating about their axes in the same direction, while in the latter there is no such preponderance of alignment in one direction more than in any other.

If you could imagine a kind of spirality of structure given to a medium, which otherwise has the same quality in all directions, perhaps by boring it full of little spiral or cork-screw cavities, all having their axes turned the same way, and all twisted round those axes in the same direction, we should have a medium which would produce the turning in question. On the other hand imagine imbedded in the heavy glass a large number of exceeding small spinning tops with their axes all pointing the same way. The reactions of these tops in the medium when they are displaced in consequence of the transverse displacement, would just be the forces required to account for the turning, independent of the direction of the light, which is observed in the magnetic field.

Thus if any theory of the propagation of light in which motion of the ether is concerned be true, this rotational element of the medium must be supplied by the magnetisation. If, however, as seems now established, we must substitute electromagnetic action for the too and fro motion of the parts of a strained and rigid ether, this light on the nature of magnetisation will lose its familiar meaning for us; but there will still be a correspondence between the phenomena in the two theories, and we shall be able to use the analogue of the rotation here imagined in explaining what magnetisation is. But this necessarily requires a better knowledge than we as yet have of the *rationale* of electric action in the ether. A perfectly satisfactory theory of turning can be given by supposing ions to move in circular orbits in planes at right angles to the lines of force. These ions correspond precisely to the spinning bodies of the ordinary dynamical theory.

We must now trace the rise of that general dynamical theory, and that system of absolute units and absolute measurement which has done so much for electrical progress in times nearer our own day. The discoveries of Faraday, Henry, and others, have been brought within the scope of a mathematical theory of inductive and electromagnetic action, by the labours of several great men, among whom may be mentioned Gauss and Weber, F. E. Neumann, and von Helmholtz in Germany, and Green, Thomson (Lord Kelvin), Maxwell, and Joule in this country. It was seen how electric currents, magnetic fields, and so forth, could be measured and have their intensities expressed in terms of units which various considerations suggested. In particular, Helmholtz and Thomson worked out the mathematical theories of electric and magnetic action and of electromagnetic induction, and placed them on a sure basis by regarding electric circuits and magnetic distributions as dynamical systems, to which the laws of conservation, transformation, and transference of energy, as given by dynamics are applicable. Thomson's papers are to us especially interesting. They were written by a man who, throughout his active career, has been in constant touch with the Philosophical Society, to which many of his results have been communicated when obtained. Though he has become better known to many of the younger generation at the present time as Lord Kelvin, yet Thomson's method of electric images for the investigation of electric distribution, Thomson's theory of electromagnetism, the Thomson effect in thermo-electricity, Thomson's theory of the electromotive force of the voltaic cell, and his general theorems in different parts of dynamics—theorems of wide application in general physics, will be quoted so long as physical literature endures, and physical research is carried on. His splendid series of electrometers for the absolute measurement of electric potential over both small and large ranges, not to speak of the standard instruments for use in both laboratory and workshop which he has more lately invented, in themselves form a very great achievement. They have been from time to time described to the Society in special papers.

On Thomson's mathematical theory, a theory singularly free from unnecessary assumptions and directly related to the observed facts, Maxwell based his great essay on the Electromagnetic Field, which he afterwards developed into his celebrated treatise on Electricity and Magnetism. In that essay, and later and more fully in his treatise, Maxwell set forth his electromagnetic theory of light, in which an argument was stated for the novel and at first sight startling view, that light is an electromagnetic phenomenon, that in fact there are two quantities which vary harmonically with time and with distance travelled along a wave, and that these are electric and magnetic force. These replace the transverse displacement or motion of parts of the medium which in the older elastic solid theory of the ether was regarded as the characteristic change in the medium which was propagated in a light wave. We shall return presently to this theory, in the meantime we ought to tarry for a little to consider first thermo-electricity, and then systems of units and methods of measurement.

It was found by Seebeck in 1822 that when a circuit is formed of two different metals (without any cell or battery) a current flows round the circuit if the two junctions are not at the same temperature. For example, if the two metals be rods of antimony and bismuth, joined at their extremities so as to form a complete circuit, and one junction be warmed while the other is kept at ordinary temperature, a current flows across the hot junction in the direction from bismuth to antimony. Similarly if a circuit be made of a copper wire and an iron wire, a current passes across the warmer junction from copper to iron. The current strength—other things being the same—depends on the metals used; for example, bismuth and antimony are more effective than other metals.

It was fouud by Peltier that when a current, say from a battery is sent round such a circuit, that junction is cooled and that junction is heated by the passage of the current, which, being respectively heated and cooled, would without the cell have caused a current to flow in the same direction. Thus the current produced by the difference of temperature of the junctions causes an absorption of heat from the warmer junction, and an evolution of heat at the colder junction.

Shortly after Seebeck's discovery it was found by Cumming that when the hot junction was increased in temperature the electromotive force increased more and more slowly, at a certain temperature of the hot junction took its maximum value, and then as the temperature of the hot junction was further increased began to diminish, and ultimately, at a sufficiently high temperature, in most instances changed sign. The temperature of maximum electromotive force was found to be independent of the temperature of the colder junction. It is called the temperature of the neutral point, from the fact, that if the two junctions of a thermoelectric circuit be kept at a constant small difference of temperature, and be both raised in temperature until one is at a higher temperature than the neutral point, and the other is at a lower, the electromotive force will fall off, until finally, when this point is reached, it has become zero.

The subject of thermo-electric action has been investigated from the point of view of thermodynamics, by Lord Kelvin, who has deduced this last result from theory, and moreover discovered the electric convection of heat in a conductor in which there is a gradient of temperature. The thermodynamic discussion showed that the absorption of heat at the hot junction, and the evolution of heat at the cold junction, are proportional to the absolute temperatures of the junctions. If then the excess of heat absorbed above that given out were the only source of energy in the circuit, the electromotive force of the couple should be proportional to the difference of temperatures. Experiment shows that this is not the case. The only other conclusion is that when a current flows round a circuit from hot to cold in certain parts, and from cold to hot elsewhere, heat is absorbed and evolved in the unequally hot conductors, to a difference accounting for the remainder of the electromotive force. A current flowing from hot to cold in copper evolves heat, and in the same circumstances in iron absorbs heat. The effects are reversed by reversal of the current. A great deal of most valuable work on this subject, in the investigation of the thermo-electric diagrams (diagrams giving all information as to thermo-electric phenomena) of many substances, was carried out by the late Professor Tait and his pupils.

As electrical science advanced it became clear that if the work done by one experimenter was to be capable of being utilised by another, results would have to be expressed by other units than those in common use. These were units based on instruments which were in the experimenter's possession, and depended in many cases on the manner in which these instruments were arranged for use. For example, I have seen such statements as this among early records of experiments: "The current was that produced by six cells of my large battery working through the circuit of the coil and galvanometer, and deflected the needle of the galvanometer through 40°." Or again—"A very strong current is necessary for this experiment, the current actually employed dashed the needle of the galvanometer against the stops."

Here, obviously, without a great deal more information, it is impossible for anyone to repeat the experiments with the same current, or to form even an approximate notion of the exact conditions under which the result was obtained.

If, however, what we may call an *absolute* unit of current, that is a unit entirely independent of instruments, locality and conditions of experimenting, had been agreed on and used for the expression of the current employed, another experimenter would have been able, with merely information as to coils, etc., to repeat the experiment, using any available batteries or any galvanometer he might find convenient for the production and measurement of the current. The need for direct and easy comparison of results obtained at magnetic observations led Gauss, in 1833, to write his fundamental paper on magnetic units and measurements, entitled *Intensitas Vis Magneticae Terrestris ad Mensuram Absolutam Revocata.*

But the matter became much more serious from the point of view of business and of practical men when submarine cables began to be constructed and laid. Such a cable cost many hundreds of thousands of pounds, and its state while being laid, and afterwards when being worked, had to be tested from day to day. It was absolutely necessary that the results of the tests made at one time should be directly and easily comparable with those made at other times. Hence, it was necessary that the capacity of the cable, the resistance of its insulating covering, and the resistance of its copper conductor, all as deduced from appropriate tests, should be expressed in terms of units in no way dependent on the apparatus used from time to time, or the locality, or other accidental conditions.

The necessity for a system of such units was recognised by the British Association for the Advancement of Science, and a committee was appointed, I think in 1861, and made its first report at the Cambridge meeting in 1862. One of the first duties of the committee was to agree upon a unit of resistance, wherewith to express the electrical resistance of coils and other conductors of currents of electricity. It was shown that a system of units could be based upon either of two ideas, (1) On a previously defined unit of magnetism defined as that quantity which placed at unit distance from an equal quantity is repelled with unit force; (2) On the idea of unit quantity of electricity defined by its electrical repulsion of an equal quantity of the same kind placed at unit distance from it. To explain the units derived from these fundamental notions would take me much too long, would involve, in fact, my giving a full course of lectures on the subject. Suffice it to say that units of current, resistance, electromotive force and capacity, were derived in each case, and the relations of the various units in the two different systems were investigated.

After the formation of the systems of units there came the great question of the realisation of the units. The first system mentioned above was found to be the more convenient for practical purposes, and in it the unit of resistance was found to involve the fundamental units of length, mass, and time, in the same way as does the ordinary dynamical quantity velocity—that is it involves the unit of mass not at all, and the other two units of length and time just as does velocity—so that a resistance was expressed properly, as so many units of length per unit of time. The unit of mass adopted was the gramme, the unit of length the centimetre, and the unit of time the mean solar second. The unit of resistance was thus a resistance expressed by 1 cm. per second. This unit was too small for practical purposes, and a multiple of ten million times the unit was adopted as the practical unit of electrical resistance, that is to say, a resistance which might be expressed as ten million centimetres per second, or one earth quadrant per second. This unit it was proposed to call the *Ohm*, from the name of the German physicist who gave the conclusion known as Ohm's law, to which reference has been made above.

The first method adopted by the B.A. committee for the realisation of the Ohm, that is, for the construction of a coil of wire which, at a definite temperature, should have a resistance of one ohm, was that of the revolving coil. It was pointed out first, I believe, by Sir William Thomson, that if a coil like that of an ordinary tangent galvanometer had its circuit completed by connection of the ends of the wire composing it, and were set up in a vertical position, and were whirled about a vertical axis in the earth's magnetic field, a needle suspended at the centre of the coil would be deflected by the induced currents generated in the coil by each half turn in the field. For, let the coil be given with its plane in the east and west position, the horizontal component of the earth's field gives a certain magnetic induction, as we call it, through the coil, which is reversed relatively to the coil when the coil is turned through 180°, so as to face the opposite way. Thus, if I be the induction at first, a change $2I$ takes place in the half turn. While the induction is thus diminishing from I to $-I$, there is on the whole a flow in the coil which tends to turn the needle in one direction. In the next half turn the induction changes from $-I$ back to I, and there is a flow in the opposite direction through the coil. But as the coil at any instant has been reversed in space from the position occupied at the corresponding instant in the previous half turn, the direction on the action of the needle is the same as before.

The phase of the current does not agree with that of the change of induction, on account of the action of the self-induction of the coil, but the effect is only to diminish the average amount of the action on the needle.

If the coil is revolved so rapidly that the time of one turn is small in comparison with the period of oscillation of the needle, the action varies from zero through a maximum to zero again, in each half turn of the coil; but the succession of impulses thus given to the needle amounts to a practically constant deflecting action. This action is greater the greater the speed of rotation, and the greater the intensity of the earth's field, and is less the greater the resistance of the coil. But the needle when deflected is drawn back towards the equilibrium position by the same earth's field on which the deflection depends. Thus the intensity of the earth's field disappears and we are left with a dependence of the deflection on the known quantities—speed of rotation, the dimensions of the coil, and the resistance of the coil.

This relation can be expressed, and when this is done and all necessary corrections are taken into account, the resistance can be deduced from it in terms of these known quantities. Then by elementary methods it is possible to make a coil which shall have precisely the resistance of the circuit of the spinning coil, or any multiple or sub-multiple of it, and the standard is realised.

Several other methods have been proposed and used for determinations of the ohm, and the results have been compared with those of the B. A. experiments with the spinning coil. A long series of researches on this subject has been made by Lord Rayleigh, who determined with great exactness, by what is known as the method of Lorenz, the absolute resistance of a column of pure mercury of given length and diameter. This method is in a way an application of the Barlow wheel experiment described above, or rather, of the Barlow wheel dynamo which I have referred to as invented by Faraday. A current is made to circulate in a coil, and produces a magnetic field within the coil. Across this field is mounted symmetrically a copper disc which is driven round with uniform speed about its axis of figure. The result is the production of an electromotive force, which, if the centre and edge of the disc be touched by a wire, will cause a current to flow in the wire. Or if two wires be taken, one made to touch at one end the edge, the other to touch at one end the centre of the disc, the two outer ends will be like the two terminals of a cell or battery—there will be an electromotive force between them. Let us suppose now that we have a current from a battery flowing in a wire, and *A*,*B* be two points in the wire, there will be a certain electromotive force acting between these points. That electromotive force will be in proper units equal to the resistance of the conductor multiplied by the current. By properly choosing the two points we can make that electromotive force anything we please, and therefore equal to that between the terminals of the wires attached to the centre and edge of the disc. If then we attach these wires properly to the points *A B*, we can make the electromotive force between the points balance that due to the rotation of the disc, so that no current will flow in the disc or the wires connected with it. Further, the current flowing in the wire may be the very current flowing also in the coil which produces the field. Hence both electromotive forces will then be proportional to the current flowing, and the equality between them will be independent of the value of the current. Thus there remains a relation connecting the resistance of the wire, a function of the dimensions of the coil and disc and the speed of rotation. The last three things being known, the first can be found in virtue of the relation.

Instead of the wire may be used a column of mercury of a known cross-sectional area, through which the coil current, or a known fraction of it, is made to flow. Then, from a knowledge, obtained by separate experiments, of the relation between the resistance of the column of mercury and that of a wire, say of pure copper, of given length and dimensions, the ohm can be realised as a coil of wire.

Experiments by this method have been carried out with the utmost refinement by Lord Rayleigh at Cambridge, and by the late Professor Viriamu Jones at Cardiff, with practically coincident results. These, however, were in all cases about 1·35 per cent. in excess of those given by the revolving coil method, as carried out by the B. A. committee. Lord Rayleigh made an elaborate investigation of the cause of the discrepance, and succeeded, by repeating the experiment with the identical apparatus used by the committee, and again with entirely new appliances, in accounting for the most of it.

The results of the latest and best experiments may be summed up by the statement that the ohm is a resistance equal to that offered to an electric current by a uniform column of mercury 106·3 centimetres long, 1 square millimetre in cross-section, and at temperature 0° C.

From the definition of the unit of current in the electromagnetic system of units as that current which, flowing in a wire bent into a circle of radius 1, produces a magnetic field of intensity 2π units at the centre of the circle, and the means which we possess of measuring magnetic field-intensities, it is possible (for example by the well-known method of the standard tangent galvanometer, by comparison of the tangents of the angles of deflection of the needle), to measure currents in absolute units. Thus the nature of a current flowing in a wire being known, and the resistance of the wire (by comparison with that of a standard realised by one of the methods just described), the electromotive force driving the current through the wire, which is the product of these two things, can be found. Thus three units are obtained on the basis of the fundamental units of length mass and time adopted (universally now the centimetre, gramme, and second), and other units can be obtained from these in ways which I cannot here stop to explain. For example, the unit quantity of electricity is in this system the quantity conveyed in one second by a wire carrying unit current, and from this is got at once the unit of capacity of a conductor or condenser.

Now let us go back for a moment to the other system of units, the electrostatic system. In that the unit quantity of electricity is the quantity which concentrated at a point at unit distance from an equal point-charge of the same kind, is repelled with unit force, air being the medium, of indefinitely great extent, in which the charges are situated. The question arose, and it was an extremely important one in its bearing on electrical theory, as to the value of the ratio of the former unit of quantity, the electromagnetic unit, to the latter. It was shown by Maxwell that this ratio is a definite velocity. We may form an idea of this velocity in the following manner. Let a spherical conductor insulated in air at a distance from all other conductors in the field, be charged to a certain potential (or height of electrical level as we may call it relatively to that of the earth), say unit potential, in the electrostatic system of units. A spherical conductor of one centimetre radius could be charged to this potential by a single electrostatic unit of electricity. Let the conductor, starting with this radius, begin to shrink. Since the capacity of a conductor is the ratio of the quantity of electricity on the conductor, to the potential to which that quantity charges the conductor, and the capacity of a spherical conductor is equal to its radius, we see that if the sphere be supposed to shrink in radius, the potential to which the same quantity of electricity will raise it will be increased. It would be necessary, therefore, to remove electricity from the sphere in order to maintain the potential constant. If v be the speed with which the surface of the sphere is approaching the centre, the amount to be removed per second would be, numerically, simply v, since the potential is unity. This electricity given off per unit of time might be conducted away and measured in *electromagnetic* units by a standard galvanometer. The current would be v in electrostatic units, and would have some other numerical value C in electromagnetic units, which would be given by the galvanometer. Let the speed v be adjusted to make the current C through the galvanometer unity; then one electromagnetic unit would pass through the galvanometer in a second, and v electrostatic units would leave the sphere. Thus v would be the ratio of the electromagnetic unit to the electrostatic.

Now it is possible by proper arrangements to measure the same quantity of electricity in the two ways, electrostatically and electromagnetically, and so to find the value of this ratio experimentally. This has been done in various ways by several experimenters both in this country and abroad. Two distinct determinations were made in the Physical Laboratory of Glasgow University by students of Lord Kelvin, viz., Mr. Dugald M'Kichan, now of Bombay, and Mr. Rinzaburo Shida, a Japanese student of great promise, afterwards Professor of Physics at Tokio, but now deceased. All the determinations made agree in giving a value of v very approximately 3×10^{10} centimetres per second, which is exactly the velocity of light! This result is of the utmost importance in connection with the electromagnetic theory of light, regarding which I propose to say a few words in conclusion.

I must here leave the great subject of electric measurements, but it is not too much to say that nothing has been of greater advantage to the progress of electric and magnetic theory. From being merely or in great part a qualitative science, electricity has become a science of exact and delicate measurement. The system of units adopted has given a precision and completeness to the mathematical theory, and has brought electrical quantities into direct relation with the ordinary dynamical qualities of forces and work. We can measure electrical energy in ergs or foot pounds, and even that remarkable person "the man in the street" who imagines that everything should be stated in a single sentence, in a manner comprehensible by his guileless and untrained intellect, has begun to talk of ampere-hours, and watts, and kilowatts. This system of units came in great measure from the needs of practical applications, and is only one of many examples which might be adduced of the great services rendered to pure theory and research by their being kept in close association with practice. Of course true theory and true practice are never at variance, they are in fact where they overlap one and the same.

We find yet another sample of this most advantageous interaction in the development of methods of constructing, laying, and working submarine cables. The theory of slow cable signalling was fully worked out by Lord Kelvin, who applied the mathematics of periodic functions, known as Fourier's analysis, to the question. He showed that the rate of working of a cable, as tested by the number of words sent per minute, could be increased by making the copper conductor of the cable of as highly conducting quality as possible, and by obtaining material for the insulating covering of as low specific inductive capacity as possible, that is of a quality to make the capacity of the cable, considered as a condenser, or Leyden jar, as small as possible. Thus the makers of such cables were forced, against the false opinions held by some electricians of the time, to obtain copper as nearly chemically pure as possible, inasmuch as a slight admixture of impurity seriously increases the resistance offered by a copper bar or wire to the passage of a current through it. The manufacture of high conductivity copper was undertaken by Messrs. Bolton of Oakamoor Mills, near Stoke-on-Trent, and their enterprise, which met with its deserved reward, was the beginning of a great and now vastly increased branch of industry.

I should perhaps have mentioned earlier the discovery made by Rowland of Baltimore, in 1875, that a charge of electricity carried round by a rotating disc was equivalent to a current. This he proved by showing that a magnetic needle suspended near the moving charge, was deflected and tended to set itself across the direction of the line of motion of the charge element in the neighbourhood. This result has lately been questioned by Crémieu in Paris, but has lately been verified by Pender, a pupil of Rowland's, and more lately by Pender and Crémieu working together at Paris. The result is of the utmost importance in the modern theory of electrodynamics, which regards the electromagnetic field as produced by the motion of ionic charges—the charges of electricity associated with molecules of matter. Electric currents even in metals are regarded as due to drift on the whole of ions having opposite charges in opposite directions. The existence of corpuscles consisting of small portions of matter (associated with electric charges the same in amount as those of the ions in electrolysis), which have each an effective mass equal to $\frac{1}{1000}$ of the mass of a hydrogen atom, has been established by researches on kathode rays. Thus the atoms of matter would appear to be capable of being broken up.

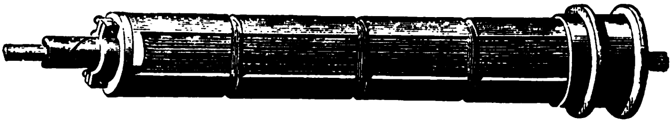
Time fails me to speak of the great practical inventors of electricity: of submarine cables and their construction laying and testing, of magneto-machines and dynamos, of telephones and microphones, of secondary batteries, and of the development of electrical engineering generally, during the last twenty-five years. I shall throw a few slides on the screen illustrative of some of these things. Here are one or two taken from photographs of incidents or operations connected with cable laying. The first shows a cable tank and the coiling of the cable in the tank at the works; the second shows the *Great Eastern* at anchor with an old frigate alongside discharging a consignment of cable to be stored in tanks on board the vessel, and thereafter to be carried out to sea to be laid.

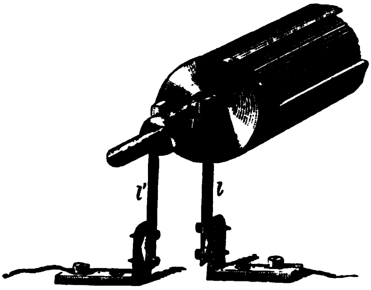
Some of you remember, many others have heard, that a telegraph cable was laid between this country and America in 1858, after an unsuccessful attempt in the autumn of 1857. The cable was laid by two ships, H.M.S. *Agamemnon*, and the U.S. frigate *Niagara*. About a year after it was laid that cable broke down completely, probably on account of the strong induction currents which were employed for the sending of signals. Its loss was a great blow to telegraphic enterprise, and a great disappointment to the two nations which it was intended it should bring into direct telegraphic communication. However, a second cable was constructed, and its submergence was begun in July, 1865, and continued until the cable broke on August 2, after over 1,000 miles had been laid. Attempts made at the time to recover the cable failed, and the company still undismayed resolved to make and lay a third cable next year, which was successfully done. Since then the number of successfully working cables has been increased to nine, and the last two were laid by the Commercial Company in 1882.

I have here upon the table the first reflecting galvanometer devised by Sir William Thomson for the reception of cable signals and used on board the *Niagara* for that purpose, (see Plate I., Fig. 3). Instruments of this kind were found afterwards to be the only instruments, among those at the disposal of electrical engineers, of sufficient delicacy to register the very feeble currents which it was recognised should be used for signalling, if long cables were not to receive injury from the process of working. The mode of action was very simple. The dots and dashes of the Morse alphabet were converted into left and right turnings of the needle, and therefore of the mirror carried by it. A current in one direction caused by the usual double sending key, gave a deflection of the spot of light towards the left hand end of the scale, which was interpreted as a dot by the clerk who sat looking at the scale; a current in the opposite direction produced by depressing the right hand button, gave similarly a dash. The different combinations of dots and dashes gave the letters of the message sent. This instrument, it is not too much to say, made submarine telegraphy commercially possible.

The use of the mirror galvanometer as receiver lasted until it was superseded by another instrument—the siphon-recorder—also invented by Sir William Thomson—which wrote the message by left and right deflections of the point of a siphon-pen across a ribbon of paper, drawn past it by clockwork. One remarkable feature of this new instrument was the avoidance of friction between the point of the pen and the paper, and the reinforcement of the action of the feeble currents, by causing them to act on the strong magnetic field of an electromagnet excited by a current from a powerful battery at the receiving station. The feeble current sent through the line from the sending station, passed through a coil of wire, vertically suspended in the magnetic field of the electromagnet, with its plane parallel to the lines of force, and kept in that position by the action of two threads made to pull downwards in that plane by weights at their lower ends. The field at the coil was intensified by a fixed core of iron, which the coil surrounded, and which therefore condensed the lines of force so that the greater number crossed the vertical sides of the coil. By the electromagnetic action between a current and a magnetic field (described above in connection with Barlow's wheel), when the line current passed round the suspended coil, one vertical side moved forward horizontally across the lines of force, the other vertical side moved back, that is the coil turned about a vertical axis. As it turned it moved in one direction or the other the lower extremity of the siphon above mentioned. The upper extremity dipped in a bath of blue aniline colour, contained in a metal vessel supported on an insulating support, and electrified by a small induction machine driven by a small electric motor. The paper where it passed the siphon was in contact with a metal roller which was uninsulated. Thus the ink being electrified was attracted towards the uninsulated metal, and was driven out in a stream of minute drops on the paper, and gave an apparently continuous, but really closely dotted line. It is this beautiful instrument that is in use at the present time as telegraphic receiver at submarine cable stations.

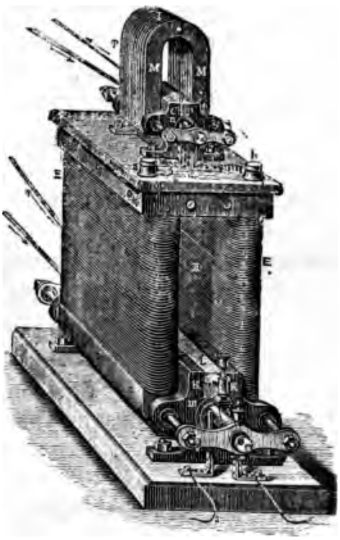
Some of you may remember a lecture on Electric Lighting, or a similar subject delivered some twenty-six or twenty-eight years ago by Sir William Siemens in the City Hall, Candleriggs. At that lecture he there showed a number of electrical generators of the Siemens type of the time. Here is a slide showing the armature of such a machine. You see it is a long cylinder with the coil wound like the thread in a shuttle, the two ends being brought out to two conducting plates on opposite sides of the spindle of the coil. On these plates pressed the brushes so that the current was reversed twice in the coil at each turn of the spindle. In the external circuit, though it always flowed in the same direction, the current rose from zero to a maximum and fell again to zero twice in the same time.





The drum or ring armature wound in a large number of sections, connected up in such a way as to give always as nearly as possible a constant electromotive force in the working circuit, had not yet been invented. It came shortly after in the Gramme ring, and in the drum armature of Siemens and Halske.

In the earlier electrical generators the magnetic field in which the armature revolved, was furnished with steel magnets permanently magnetised. Many of these magneto-machines, as they were called, were alternating machines, that is they worked without commutators, and the current, when reversed in the revolving coil was reversed also in the working circuit. These steel magnets, whether for continuous current machines or for alternators, were replaced by electromagnets fed by current from an auxiliary magneto, and an enormous increase of power was the result. This was first done by Mr. Wilde of Manchester, to whom belongs the credit of having introduced the electromagnetic field magnet. The next step was to make the machine self-exciting, by sending the current (or a part of it) which flowed in the working circuit, and generated by the machine, through the electromagnet coils, so as to produce the magnetisation of their cores, and give rise to the magnetic field. When this process is carefully considered, the first question that occurs to one is how the action of the machine is to be started; for if the magnet is fully demagnetised when the machine is not running, no current will flow when the armature is set going, since there is no field and no lines of force to be cut by the revolving coils. The answer is that the field is not zero at starting. A small amount of residual magnetism is left in the cores, and this suffices to give a small current in the armature, when that is made to rotate fast enough and at the same time has its circuit closed through a resistance which is not too great. This current flowing through the magnet coils still further magnetises their cores, and increases the field. As the rotation continues in the enhanced field, a greater current flows, and the field is still further



increased, and so on until a limit is reached in consequence of the saturation of the magnets.

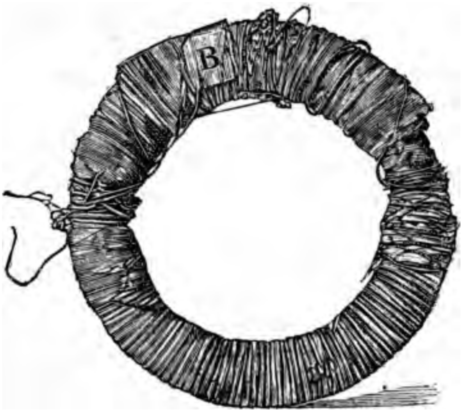
It is remarkable that this method of excitation of the field magnets was proposed at the same meeting of the Royal Society in February 1867, by two different inventors, Dr. C. W. Siemens, afterwards Sir William Siemens, and Sir Charles Wheatstone, and it appears that the same idea had been more or less clearly suggested previously in a patent of Mr. C. F. Varley. The discovery of self-excitation was also communicated to the Berlin Academy at the same time, by Dr. Siemens' brother, Dr. Werner Siemens, who seems to have been the originator of the idea, so far as the brothers Siemens were concerned.

Maxwell, in one of his papers, calls attention to the remarkable fact of the reversibility of a continuous current machine, that is to say, the possibility of converting it into a motor by sending into it a current from another continuous current generator, or from a battery. This is exemplified in the Faraday disc dynamo, and the Barlow wheel arrangement; but it is the foundation of the method of transmission of power. For a time the conditions of motor working were not fully understood; but it is now long since very great success in the transmission of power to considerable distances from a generating station was achieved. We now have Niagara partly harnessed to work in this way, and a scheme for power transmission in the Clyde Valley is in course of being carried out.

I must mention here in connection with continuous current dynamo machines, the very remarkable work of the late Dr John Hopkinson. By his application of the magnetic circuit, and his investigation of the characteristic curves of machines, he gave a means of testing the performance of a dynamo comparable with the indicator method for steam engines. Previous to Hopkinson's work, no very clear ideas seem to have prevailed as to the best construction of dynamo-magnets and the arrangement of the machine; that is to say the magnetic circuit of iron cores, yoke connecting these, and armature core between the poles, was not fully understood. It appears to have occurred to Edison for example, that the legs of the electromagnets used for dynamos should be made long. Perhaps the idea was that great magnetic moment in these cores was the thing wanted. If so, it was a mistake, though it is the case that long cores longitudinally magnetised, are under a smaller demagnetising force, due to their own magnetisation, than are comparatively short cores. This demagnetising force is, however, very completely avoided if a complete magnetic circuit is obtained, without air-gaps, undue constriction anywhere, and without discontinuities of cross-section giving rise to projecting corners and flanges, in short, by obtaining, as Hopkinson showed, a magnetic circuit as short, and as slightly resistent as regards magnetisation, as possible.

Edison constructed large horse-shoe magnets in the hope, which was not realised, that the machines would be effective. I well remember a test of two of these machines, made just when they came out, by Dr Hopkins and Sir William Thomson, at Messrs. Anderson and Munro's works, somewhere in Woodside. The machines had a drum armature of special design, and this combined with a properly designed magnetic circuit, is to be found in the Edison-Hopkinson Dynamo, which afterwards came into use.

Hopkinson also led the way in the elucidation of the action of alternating current machines, and discussed in a very simple manner the conditions of their arrangement in series and in parallel. Very large alternators have since been made, and the study and construction of such machines, and of alternate current motors, have now become a large department of electrical engineering.



With these developments of the older machines came the transformer. The primary and secondary circuits, wound on the two halves of the same anchor-ring core of iron wire, which were used by Faraday in his experiments on induction of currents, were really a transformer. The cut immediately adjoining shows the actual ring and coils used by Faraday.[1] The arrangement of primary and secondary coils is shown in the adjoining diagram (p. 44) which is very exactly a form of the modern transformer. The old induction coil of Ruhmkorff (really first constructed almost in its present form by Page, in 1838), consisting of a primary and secondary circuit wound round a soft iron core, was nothing but a transformer in which, by means of a secondary of many turns of wire, an alternating or intermittent current of great electromotive force was obtained from an intermittent current of small electromotive force. If, instead of an intermittent one-directional current produced by a battery, we send an alternating current from a machine, through the primary, an alternating current of the same period, but differing in phase, is produced in the secondary. The source of energy is the generator in the primary, and there is a certain loss in transformation, which, with proper arrangements, can be made a minimum. This is what is called transforming up, and is used, with good insulation, in the transmission of power, where the adoption of a feeble current of high electromotive force is of advantage.

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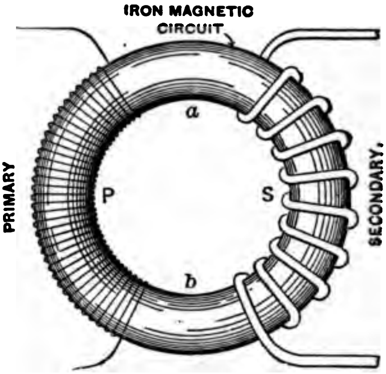
[1] From Fleming's *Alternate Current Transformer.*

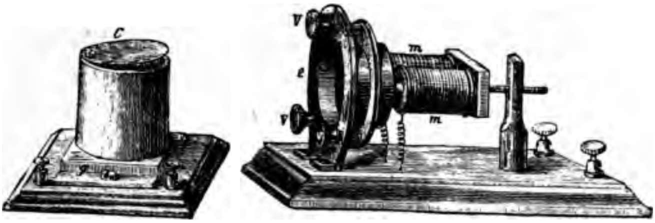


Similarly if a generator of great electromotive force is convenient and economical, or at the receiving end when high electromotive forces are employed in the transmission of power, step-down transformation can be employed. The transformer just described is reversed, the primary is of high resistance and the secondary is low. The alternating current from the latter is then of low enough electromotive force to be used safely for domestic purposes. Power transmitted over long distances may thus involve a double transformation—transforming up at the generating end, and transforming down again at the using end.

The first attempt perhaps to use transformers in commercial work was made by Gaulard and Gibbs in 1882 or 1883, when incandescent lamps were fed by a transformer system at the Royal Aquarium in London. Since then the subject has been greatly developed, and the reproach, brought against it in its early years, that it was too uneconomical for practice, has been removed. The methods of regulating and testing transformers have since been perfected, and many types, possessing advantages for different purposes, have been constructed.

The great subject of polyphase machines I must pass over, as well as such exceedingly interesting and important subjects as the mode of distribution of currents from central stations for electric lighting and the driving of vehicles, such as tramcars and railway trains. These are all of immense importance, and represent an amount of inventiveness, practical skill, and knowledge of theory, on the part of their originators and directors, which should receive some more special notice than can here be given them.

Here are a couple of slides showing the telephone invented by Graham Bell in the form in which it was first tried in this country in 1876. You will see that the iron diaphragm of the receiving instrument is held at one point of its edge above the bar magnet within the cylinder below. The other figure shows the sending instrument.



A year or so later Graham Bell brought two instruments, nearly of the modern form, to Glasgow, and I remember that very successful trials were made of them. We were able to speak by means of them from Hillhead Post Office to the General Post Office in George Square, round by Edinburgh, the wires having been joined up by the Post Office authorities for this purpose. As to the later developments of telephony in Glasgow and elsewhere I need say nothing.

I have tasked your patience already much too long, but before I close I must say a few words about the Electromagnetic Theory of Light. As I have stated, it was sketched in Maxwell's great paper *On the Electromagnetic Field* published in 1865, and was more fully set forth in his *Electricity and Magnetism* which appeared in 1873.

To fix our ideas let us suppose that I have here two knobs, let us say connected with the coatings of a Leyden jar, and suppose a discharge to take place between these knobs, in the form of an electric spark. When the discharge commences, lines of magnetic force begin to come into existence in the space surrounding the gap. These lines are closed curves surrounding the path of discharge. More properly we have tubes of magnetic force which tend to contract along their length and swell out sideways; and when the current has become steady (if it becomes so), they fill up the whole space surrounding the line of flow. As the flow increases the magnetic force at any point grows in intensity, and when the steady state has been attained it falls off with distance from the discharge-circuit according to a well understood law.

Now the question arose in Maxwell's mind whether this distribution of lines or tubes of magnetic force surrounding the path of discharge grew up in all its extent right out to the remotest parts of the medium instantaneously, or whether it began near the line of discharge, then affected the space farther out, and so on, travelling outwards, as the waves from the disturbance produced by throwing a stone into a millpond travel through the surrounding water. Maxwell adopted as a hypothesis, which he supported by various theoretical considerations, that the magnetic force is propagated outwards with the speed of light, that in fact the change in the medium is precisely that change which takes place in it as a light wave travels through it.

Moreover, Maxwell introduced the idea that all currents flow in closed circuits; and that therefore the flow of electricity along the conducting wire joining the coatings of a Leyden jar is not, as it appears, a current in an unclosed circuit. A change in the state of the medium separating the plates takes place, as the discharge proceeds the electric strain (or as Maxwell termed it, "electric displacement") and stress in the insulating medium undergo progressive change. The rate at which this change proceeds, made numerically definite in a certain way, Maxwell called the displacement current, and his view was that this displacement current completed the circuit of the conduction current in the wire. Now, when the magnetic change takes place in the medium surrounding the wire discharging (or charging) the Leyden jar, it is accompanied at each point of the medium by a displacement current. In fact, there are, according to Maxwell's view, at each point of the insulating medium, two changes proceeding which are related to one another in a certain reciprocal way; the time-rate of change of magnetic induction which may be regarded as depending on a certain mode of space variation (the *curl* as it is called) of the electric force, and the time-rate of change of the electric force—the displacement current, which depends in a similar way on the curl of the magnetic induction. These two vectors at a distance from the origin of the disturbance, in a medium which has the same quality in different directions, lie at right angles to one another in the surface which bounds the space to which at any instant the changes have spread. Or, as it is sometimes put, they lie in the wave front, always excepting the space very near the region of the discharge.

Maxwell showed that in his theory the velocity of propagation of such a pulse of electric and magnetic action is equal to the ratio of the numerical measure of a certain quantity of electricity in electrostatic units, to its numerical measure in electromagnetic units, in other words, to the ratio of the electromagnetic unit of quantity to the electrostatic unit referred to above. If then it was found, and we have seen that it has been found, that this velocity of propagation was the velocity of light, it would be a confirmation, so far as it went, of his view that this propagation was essentially identical with the propagation of light.

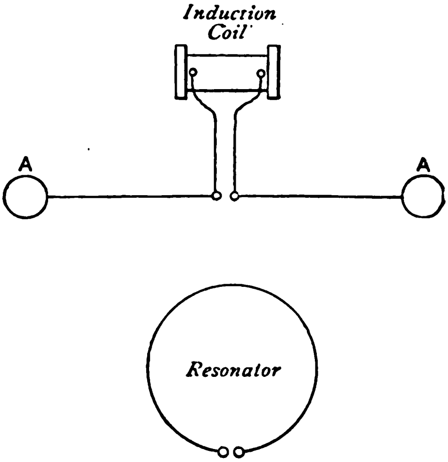
It remained, however, to produce a succession of electric disturbances varying and succeeding one another like the vibrations of a tuning fork, and to test whether the corresponding electric and magnetic effects travelled out at a finite velocity, like the vibrations of the fork. This, it will be seen at once, depended on the possibility of producing an oscillating discharge, that is, a discharge first in the positive direction, say from terminal A of the jar, to terminal B, then in the negative direction, then in the positive direction again, and so on. Now the existence of such an oscillating discharge had been suspected as early as 1845 or 1846, from some puzzling phenomena of the magnetisation of magnets by Leyden jar discharges, which were so explained by Helmholtz in his famous essay, published in 1847, on the Conservation of Energy. The full theory of such a discharge was given by Lord Kelvin in a paper on Transient Currents, published in the *Philosophical Magazine*, in 1853. He there shows that if the two plates of a condenser of capacity C, say the inner and outer coatings of a Leyden jar for example, be connected by a coil of wire possessing resistance and self-inductance which we may call R and L, the discharge is oscillatory provided $4L$ be greater than R^2C. That is, if the condenser be charged, and then the plates connected by the coil, a flow will take place from the positive plate to the negative, which will not stop when the potentials have been equalised, but will continue until the formerly positive plate has become negative, and the negative positive; then the discharge will take place the other way, with again reversal of the potentials, and so on: the flow will go on causing the state of change to continually overshoot the zero state, just as a pendulum, as it oscillates, moves backwards and forwards, continually overshooting the vertical position. A gradual expenditure of energy in overcoming resistance and, as we now know, also in wave radiation, however, causes the condenser plates to ultimately assume the state of equality of potentials, just as the resistance of the air in time consumes the energy of the pendulum, and causes the pendulum to settle in the vertical position. On the other hand, if the self-inductance be smaller than the value which fulfils this inequality, the discharge is one in which the potentials of the plates are gradually equalised by a flow which is throughout in the same direction.

In point of fact the system behaves just as if it had inertia L, were under a resisting force equal to R times the current, and were brought back towards the zero state by a spring which gives a force $1/C$, when stretched by unit distance. In fact, pursuing the pendulum comparison, the condenser and its circuit is in every way analogous to a pendulum, the bob of which (of mass L) is pulled back towards the zero position by a spring with a force proportional to the displacement from that position, and moving in a resisting medium like treacle, has its motion resisted with a force directly proportional to the velocity v, equal in fact to Rv. The equation of displacement for the pendulum is precisely the equation of potential for the condenser. This inertia and spring are no doubt due to the fact that the medium has to be changed by the imposition of the strain involved in the electrical and magnetic polarisation, when the condenser is charged, or by the removal or modification of the polarisation when discharge is going on.

It was possible, therefore, to obtain an oscillating discharge and to investigate the propagation of its effects in the surrounding medium. If it were found, on such an investigation, that waves of electric and magnetic force existed in the medium, that is to say, if on examination of the state of the medium from point to point outwards, at any instant, it were found that, the magnetic or electric state, varied in a manner corresponding to that in which the air displacement or density varied along the train of sound—waves travelling out from a source, the existence of electromagnetic waves would be established.

The verification by experiment depended on getting a suitable exciter and receiver for the waves. We can start sound-waves by a tuning fork, and set up a system of standing waves by using a reflector, and examine the wave at different points in its line of propagation by means of a suitable indicator such as a flame supplied with gas, the pressure of which is affected by the vibrations of a membrane actuated by the waves. Or we might dispense with the reflector and use a resonator and explore the space round the fork and note that at certain places the sound is strong, and at others sinks away to silence. Professor Fitzgerald of Dublin proposed a magnetic exciter, but the system was difficult to work, and nothing came of the proposal. In several valuable papers, however, Fitzgerald showed how such waves might be experimented on, and how their energy could be calculated by means of Poynting's theorem of the flow of energy (see below).

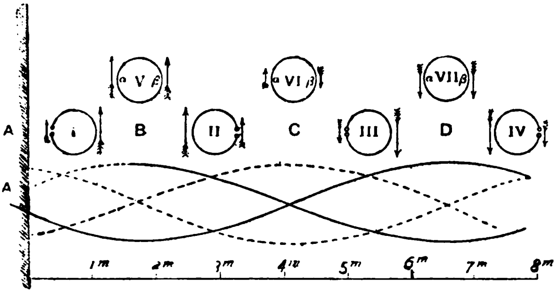
The experimental verification was successfully carried out in 1887, by Heinrich Hertz, Professor of Physics in the University of Karlsruhe, a pupil of von Helmholtz, by whom the research was suggested. Hertz used an electric exciter which took different forms. One is easily described. Imagine two large metal dumb-bells, each about 20 inches in diameter, connected with a somewhat thin wire stem, broken in the middle by a narrow gap, as represented in the diagram. The two sides of the gap are connected to the terminals of the induction coil. The spheres are charged by the coil until a spark passes across the gap. That spark represents when analysed, for example, by a revolving



mirror. an oscillating discharge. The spheres have capacity which is easily estimated, the connecting stem and the gap, which becomes part of the conductor when the discharge is passing, have resistance and self-inductance. The latter can be calculated, and also the period of the disturbance, which is by Lord Kelvin's theory, if the small resistance be neglected, $2\pi\sqrt{LC}$.

The period of the waves (if there really were any) being thus known, a receiver or resonator was employed to ascertain their existence. This consisted, in many of the experiments, of a wire ring about 34 inches in diameter. At one point was a narrow gap terminated by two small knobs, as shown in the diagram. When the centre of the receiver was placed in a horizontal line through the centre of the exciting spark gap at right angles to the line of discharge, and the plane of the receiver was made vertical, sparking took place between the knobs of the receiver when the gap was parallel to the exciting discharge. When the receiver was turned round in its own plane through 90° so that the spark-gap in it became vertical, no sparking occurred, and the sparking reappeared again when the ring was turned as before round its own axis through a further angle of 90°. Other positions were tested with similar results all showing that the position of the spark-gap all important. This dependence of the sparking on the position of the spark-gap was conclusive against its being an inductive effect of one circuit on another, produced according to the ideas of induction which formerly obtained.

The next thing was to get a definite system of standing waves. For this the waves were reflected from a large vertical plate of zinc, 4 metres high by 2 metres broad, which covered the middle part of one end wall of the Physical Lecture Room. The exciter was an arrangement similar to that described above, except that it had a pair of square plates in a vertical plane instead of the two balls. This was placed with its axis vertical, at the middle of the end of the room, remote from that covered by the zinc plate. The diagram shows the zinc plate P, the direction of propagation, and gives by the dotted lines an indication of the direct and reflected waves, and by the full lines the standing waves. The circles show the positions of the receiver with its spark-gap. The positions I., II., III., IV. are those of most intense sparking, V., VI., VII. those of minimum sparking. In the former set the spark-gap was turned alternately in opposite directions, and the results are shown by the relative lengths of arrows; in the latter set the turning made no difference in the sparking. The node for the electric force was, according to the diagram, about 68 centimetres behind the zinc surface, and the wave length—the distance from position V. to position VII. was 9.6 metres. This with the calculated period, which was $3/10^8$ second, gave $3{\cdot}2 \times 10^{10}$ centimetres per second as the velocity of propagation, almost exactly the velocity of light.



Hertz also experimented on waves propagated along a wire as a guide, and obtained concordant results. There could exist no longer any doubt, that true electric waves were produced, and were propagated with the speed of light.

These waves once obtained were produced by many experimenters, and their behaviour was studied in every conceivable way. They were found to be reflected, refracted (immense prisms of pitch were made for the purpose) and polarised just like waves of light. For polarisation Hertz imitated a plate of tourmaline, cut parallel to the axis, by making a fairly close grating of parallel wires, and placed it across the path of the waves. He showed that if the spark-gap of the exciter was parallel to the wires the waves passed through the grating, and that if the spark-gap was at right angles to the wires the waves were stopped.

The facility with which electric waves penetrated such media as stone walls, banks of earth, and the like, was very wonderful. At a meeting of the British Association at Dublin, when experiments on electric waves were hardly known in this country, a circle of wire was observed lying on top of a stone pillar in the grounds of Trinity College, and apparently unconnected with anything. When it was closely observed it was found to have in it a narrow gap across which a stream of sparks was passing. The exciter was within the physical laboratory not far off, and the waves passed through the separating walls apparently without the least alteration.

It is obvious that in this wave transmission, which Hertz showed how to produce and detect, we have the beginning and a good deal more of wireless telegraphy. It is not so generally remembered, when we speak of Marconigrams and the like, how immense was the step taken by Hertz and the other pioneers in the investigation of electric waves.

Prominent among the experimenters and theoretical writers on electrical waves in this country were Fitzgerald, Lodge of Liverpool, J. J. Thomson, and Larmor at Cambridge, and Oliver Heaviside. Lodge gave many interesting results of discharge in currents of different kinds, and, in the course of work which he was carrying on while Hertz was engaged in his researches, also, like Fitzgerald, came very near to making the discovery of wave propagation. Larmor has given a theory of æther and matter which probably is more far-reaching and comprehensive than any other; and J. J. Thomson has added to Maxwell's treatise a supplementary volume containing much original matter of great importance as elucidating and verifying modern electromagnetic theory, and the theory of waves in particular. Oliver Heaviside has written a long series of mathematical papers in which with remarkable physical power and instinct, he has worked out and unified the Maxwellian theory, and has discussed, and in considerable degree, originated the later theory, which I can here only mention, of the magnetic effects of moving electrical charges. But no one did more for electrical science during the last twenty years, by his original papers, by his influence as a teacher, and by his inspiring advice and counsel than Fitzgerald; and his death two years ago was a heavy loss to science

Here I may mention Poynting's theory of the Flow of Energy in the electromagnetic field, though in point of time it came before the period of wave investigation by experiment. Basing on Maxwell's theory Professor Poynting gave reason for supposing that the flow of energy in the discharge of a condenser, for example, was sideways from the strained medium towards the unstrained. The tubes of electric force which extended between the plates thus moved laterally out with their ends on the plate, and finally on the wire. Thus, as the tubes moved they shortened, being gradually absorbed, and having their energy dissipated in heat in the wire. Thus, for example, the current from a battery, along a submarine cable, consists of the passage along the cable of tubes of electric induction in the insulating covering with their ends on the conducting line and the sea-water. These tubes originate at the places where chemical action takes place, come out into the insulating covering, and pass along using the wire only as a guide, but giving up to it a certain amount of energy in the form of heat caused by partial absorption of the tubes by the conductor, since this results in motion of its particles which is resisted by friction. Thus the energy from a generating machine really passes out into the medium surrounding the conducting wires. This medium is the real vehicle of the energy, the wires are only the guides which enable the energy to converge again upon the motor or electric lamp, in which it is to be utilised. Thus in this view nothing flows along the wire, which is a mere regulator of the motion of induction tubes in the ether.

I could have wished to speak of the effect (discovered by Zeeman of Leyden) of a magnetic field on the spectrum of a source of light situated in the field, a discovery which is curiously related to Faraday's magneto-optic experiment, to speak also of kathode rays, Lenard's beautiful discovery, and of the Röntgen rays to which they give rise in certain circumstances, but time forbids. With Röntgen rays and their effects you are tolerably familiar, and it is pleasant to remember that the work of Crookes very materially contributed to their discovery by Professor Röntgen in Germany. These rays have given certainty to surgical operations, where before all was comparative groping in the dark, and they afford powerful therapeutic agency in certain diseases which before were intractable. It is certain that the kathode rays are streams of negatively electrified particles, which fly from the kathode of a sufficiently exhausted vacuum tube, and it seems almost certain that the Röntgen rays which these particles produce by their impact with the glass walls of the tube are light waves of exceedingly small wave-length.

Then quite recently we have had the Becquerel rays, rays given off continually, in the dark, by bodies of nearly every kind, which affect a photographic plate when that is sufficiently long exposed to their influence. Almost all bodies have been found to be more or less thus radio-active, and some such as uranium, polonium, and thorium, very highly so indeed. And, most recent of all, we have, through the patient long continued work of Monsieur and Madame Curie in France, the discovery of radium, the most radio-active of bodies, thousands of times more radio-active than uranium, the most active of all other bodies. Here, it has been suggested, we appear to have, as perhaps we have in much smaller degree in the other cases, the breaking down of the atoms of the substance into particles, of which it is computed there are something like 1,000 in the atom of hydrogen.

What then am I to say of the astonishing phenomena of radium? Only this, that so far as we know them, they are not in any way subversive of the laws of physics, for example, of the principle of the conservation of energy. The real fact is that we are able to draw in radium, and in an almost infinitesimal degree in other cases, on a store of energy, formerly supposed unavailable. I will say nothing further now. A lecture is to be delivered in a few days, under the auspices of the Glasgow Science Lectures Association, by Mr Frederick Soddy, one of the men who have worked and made discoveries in this line of research. The investigations carried on by Professor Rutherford at Montreal, and by Sir William Ramsay in London, in conjunction with Mr Soddy, are well known, and I will leave you to learn about radium and radioactivity from him.

Well, now, I have tried in a very imperfect way to trace the progress of Electrical Science during the last 100 years, and we have seen that the progress made has been very great indeed in comparison with what had been done before. A hundred years hence someone may try to sketch the progress of Electricity in the twentieth century, and he may be able to say, and from the rapidity of discovery I believe he will be able to say, that much more had been done in the twentieth century than was accomplished in the nineteenth. But whatever is done there can be no doubt that that work will be based on the discoveries of the men to whom I have referred in the course of the present Lecture, will be due to Faraday, Helmholtz, and Kelvin, to Rayleigh, Hertz, and Fitzgerald, and to many others. I feel sure that whatever happens these names will always be held in imperishable renown.

Introduction to a discussion on *The Fiscal Policy*, by Professor WILLIAM SMART, Phil.D., LL.D. The discussion was arranged by the Economic Science Section, and took place at the meeting of the Society on 2nd December, 1903.

AMONG the many statements made, during this great enquiry, which I should deny, is the statement that the prosperity of a country is to be gauged by its Foreign Trade. Whether it is so or not, and in what measure it is so, depends on circumstances. With some countries, foreign trade is a necessity; with others, it is not. If a country has specialised in the making of things which require a foreign raw material, it must have that raw material. If it has specialised in a trade carried on outside the national boundaries, and yet not within the national boundaries of any other country—the No-Man's Land of the sea—it must take payment for the product of that industry in foreign goods. If it is rich, and its people must have comforts and luxuries grown only in climates different to its own, it must bring these from abroad. If it has lent money to foreign states, and invested capital in foreign industries, it must take its interest and profits in foreign goods. But if a country is large enough to have within its boundaries all manner of raw material and all extremes of climate; if it has no ocean going shipping; if it has not lent or invested capital abroad, but is yet so young and undeveloped that it can employ all its capital actively at home; I cannot see either that it must have a foreign trade, or that its foreign trade is a sign and measure of its prosperity.

In comparing our progress with that of other countries, this cuts two ways. When it is said that we are falling behind because we are not increasing our foreign trade so fast as some other nations, I should raise two points:—(1) whether the increase of their foreign trade is an unquestionable proof of their advancing prosperity; and (2) whether our further progress must needs take the shape of proportional increase.

As regards (1). Only a year ago, if I remember aright, it was generally accepted that the reason why America was not exporting steel, but, on the contrary, importing it, was the extraordinary demand for steel in America, owing to the growth of its industries, its railways, and its buildings. The same was said of us in the early nineties; we were so busy that we had relatively little to send to foreign countries. In this case, the stoppage of exports was a sign of prosperity. Again, I notice that it is pretty generally agreed that the American and German export of which we so much complain, namely, the Dumping of cheap goods here, is a phenomenon of Trusts. In lectures given in the University, and in a paper read before the Society of Arts a year ago, I pointed out that we had more reason to fear the American Trust than we had to fear our own Combines. I said the Trust system involved that American goods would enter our markets and neutral markets under the encouragement of a bounty, not a bounty on one article but a bounty on all articles made by Trusts and exported. The reasoning was this. Large production is cheap production. But large production has a limit in consumption. It might easily be the case, in any industry, that so much was produced that consumption could not take it all off at a price that would pay. But if such an industry has a great outside market in which it may sell any surplus that could not be disposed of at home without bringing down the prices at home, the one limit to large production is removed. Now, in virtue of Protection, outside competition is shut off, and, in virtue of the Trust, inside competition is shut off. Under this double monopoly, home prices in the protected country may be maintained at a level only a little below the cost price of the imported articles plus the duty. In these circumstances, the only thing that could bring down the high prices would be over production. But the surplus is "dumped" on us, and the American producer—and consumer—continues to enjoy his monopoly prices. It is on a large scale very much the phenomenon of the "cheap sale;" the warehouse gets rid of its superfluous stock by selling for a fortnight at cost, and sells for the other fifty weeks of the year at remunerative prices. Now, will anyone say that this Trust system is a healthy system? It may be bad for us; is it good for America? Ask the Americans themselves, from the President downwards; ask why they have tried all manner of legislation against it; and you have the answer. But if the export of surpluses is a necessary accompaniment of the

Trust system, can it be said that the increase in American exports is any necessary sign of American prosperity?

My first point, then, is: that a stoppage of exports may be a sign of progress, while an increase may not.

As regards (2). Even if it were the case that our foreign exports were stagnant, I should not be convinced that our prosperity was on the wane. I should ask as to the state of industries within the country, to see if it might not be the case that our increasing capital and increasing labour were taking the direction of industries which did not depend on exporting. If I found that the extent of such industries, and the business done, was a "trade secret" that cannot be brought to the test of statistics, inasmuch as there are no government figures of quantities and values such as give us the information in foreign trade, I should take the other tests of national prosperity. I should take the evidence of my own eyes as to the standard of living of the people; their diet, their housing, and, particularly, their little extravagancies, such as bicycles and holidays. I should ask as to money wages, and, much more important, as to the purchasing power of wages. I should ask as to the savings of the people—not as to Savings Banks returns only, but as to the amounts in Co-operatives, Friendly Societies, Trade Union funds. I should ask if Giffen's figures were accepted that the National Income, in money figures, was £1,200,000,000 in 1875, £1,350,000,000 in 1885, and £1,750,000,000 now. I should ask the evidence of the Income Tax returns, remembering that our incomes up to £160 are untaxed, and not fully taxed till £700 is reached, while Germans are taxed down to £45. I should ask if it is true that a penny on the Income Tax yields £2,500,000 after three years of war expenditure, as compared with £2,250,000 ten years ago.

If, by all these tests, the state of the nation showed up well, not only absolutely but relatively, then I should turn to foreign trade. I confess I should not come to the enquiry with a mind quite unbiassed. I should expect to find that our foreign trade was increasing. I should not, in reason, expect to find it keeping pace, in total values, with that of foreign countries already greater in population and growing more rapidly than ourselves; but I should look for an increase per head of population. I should do so, first, on the ground that, as industry increases, we shall import more raw material, and, as the division of labour increases, we shall import more partly manufactured material. I should do so, second, on the ground that the rising standard of life demands more of such things as sugar, tea, tobacco, wines, fruits, and, above all, grain. (I say "grain," because, so far as I can see, as the cultivable area of our little country is encroached on by cities, our agricultural demand will be a kind of home-farm demand, for such things as fresh dairy produce, meat, vegetables, grass). I should do so, third, on the ground that, as our wealth increases, our foreign loans and investments will increase.

Approaching the matter with this expectation, I should turn first to Imports. Well, I am sure that I should not find my expectation belied in this quarter. If there is a fact which is accepted—indeed mourned over—it is the continuous and enormous growth of our imports. One part at least of our foreign trade is entirely satisfactory.

Then I should turn to the Exports. And here a host of politicians would eagerly lend me their guidance to show what a falling off is here; to all appearance, a "debit balance" of no less than £161,000,000 a year, taking the average of the last ten. I do not know exactly what some people make of this. Last year I found such expressions as that the "a balance of imports is the same as a merchant's net loss," and Mr Seddon won immortality for himself, in the annals of historical economics, by saying it meant that £161,000,000 golden sovereigns left our shores every year. But ignorant views like these are no longer ventilated.

I should, I confess, narrowly criticise this "debit balance." I think the first thing I should ask is if we are exceptional in having such a balance. I find that, if a "debit balance" is a sign of decay, at least we have good company to lighten the downward path. Germany has a similar balance of about £50,000,000; France, some £23,000,000; Holland, £21,000,000; Belgium, £12,000,000; Italy, £14,000,000; even Russia, £5,000,000. I should ask, next, if any country had a balance on the other side. When I found that the Danubian kingdoms and the South American republics generally had a "credit balance," and that the United States is perhaps the one great country which shows such a balance, I think I should ask myself if a "credit balance" is really a sign of prosperity. Then, perhaps, a twist of memory would put into my head something I once heard said by a shipowner, that the final destiny of most ships was, not to be broken up, but to go down at sea, sometimes with all hands, always with all cargoes; and I should expect that more goods on the whole leave the world's ports than ever arrive in the world's ports—that the world's exports are greater than the world's imports. Then, perhaps, I should be staggered with the fact that, taking the world's exports and imports as a whole, the phenomenon is just the other way about—that, tested by value, more goods arrive than ever set sail. The figures, as given by the Board of Trade are:—Imports, £2,516,000,000; Exports, £2,292,000,000 leaving a "debit balance" of £224,000,000. From which it would seem that, not only we but all the world, with the exception of the Danubian kingdoms, the South American republics, and the United States, are on the down grade!

My suspicions thus aroused, I should look still more narrowly into the apparent deficit in our exports. I should go over the Statistical Abstract to see where the falling off lay. This examination would probably lead me to see that any general conclusion was likely to be misleading, as both quantities and values vary—sometimes very widely—from year to year. I should note, however, in passing, that this is perhaps what we should expect from the rather gratifying fact that we are no longer dependent for our exports on one or two staple trades, but are exporting a little of everything we make. But when I had gone over the products of our different industries, from Alkali to Woollens, I should ask: Where does our third oldest industry appear on this list? Does Shipping produce nothing for export? Are our ships canal boats and river steamers that ply only within the country? Is this a home trade? Then I should remember that ships do not produce material goods; that they produce while they ply outside the boundaries where the statistics of export are collected; that their product is a service which is not and cannot be embodied in goods. I should remember that a great statistical authority—I say "statistical" that I may not be supposed to appeal to any of the discredited class called "economists"—many years ago had called these services—the total earnings of our shipping—our Invisible Exports; that, in 1882, he had figured out the value of these at £60,000,000, and this year had put it down at £90,000,000; and that the present Board of Trade had checked that figure, confirmed, and accepted it. (Perhaps I should say that Giffen took the British tonnage earnings at £15 and £5 for steamers and sailers respectively at the former date, and at £12 and £4 at the latter. The Board of Trade took the total imports and exports of the world—which are, of course, the same goods—as above; accepted the

£224,000,000 difference in their value as representing freights and insurance; halved it to represent our share of the carrying tonnage of the world; deducted 9 per cent. for colonial ships, and further deducted £12½ millions for coals and stores purchased abroad, harbour and other dues; and arrived at the figure of £89½ millions). And I should ask the friends who were lending me their sympathetic aid: When you speak of Exports being stagnant for twenty years, why do you not include this £30,000,000, of increase since 1882?

With my wits sharpened by this discovery, I should ask if there were not perhaps other "invisible exports." Then I should find that the same statistical authority—the greatest we have—had pointed out, twenty years ago, that Bankers' and other Commissions were services rendered to men and women and businesses abroad, of the same nature as Shipping services; that he estimated them then at some £18,000,000. And I should ask our friends: Why do you not include this figure also among our Exports?

The reply perhaps would be: You have accounted for an accidental omission of £100,000,000 or £110,000,000, or a trifle of that sort. But the balance is £161,000,000. Well, if I had accepted the homely dictum that Imports and Exports balance each other, without enquiring as to how they balance, I should perhaps be checked for a moment. But if, when I was ruminating over this, I received a cheque as dividend for shares I hold in a South African mine, I might ask: Where do dividends like this come in? I suppose the mine sent a shipment of gold or of some other commodity to enable the London agents to send out cheques to the shareholders here. This shipment of goods is not one that has to be paid; it is itself an annual payment for a sum capital. What about imports and exports here? Then I should remember that, when the mine was sinking, I and others sent out the capital to buy and equip the mine—perhaps I was the maker who supplied the machinery. I should discover that there was an export which accounts for and balances this import, but that it is an export in the past. It was capital to the value of £100 which I then sent out in order to buy an annual sum—say, an import of £5. Here is an *annual* import against which there is no *annual* export; and what we should expect to find is that, every year, there is an import which is *not* balanced by an export of that year.

So I look up the Income Tax returns. There I find that £62½ millions are returned for assessment as interest on foreign government and colonial loans, railways, and coupons; (it was £32,000,000 in 1882-3, representing an increase of nearly 100 per cent.), and that, calculating omissions and contra-accounts, the Board of Trade takes this as a *minimum* figure for income on foreign investments. Giffen and other statisticians put it at £90,000,000.

Well: what is the conclusion? Surely that, on examination of our foreign trade, we find that Imports have steadily and enormously increased and that Exports have steadily and enormously increased with them. No doubt the material exports are hard statistical facts, while the "invisible exports" and the foreign interest and profits are, to some extent, calculations. But, I ask, are the calculations denied? I have not seen them denied. I have seen, in the *Times* and other newspapers, the calculations flouted, and passed by—one statesman has called them part of the Cobdenite ritual which he and his party are going to sweep away—but of any sober attempt to deny them or confute them, I have seen nothing.

Some, indeed, appealing from the known to the unknown, and, I think, to the unknowable, have said that we are selling out our securities to pay this "debit balance," this "net loss," grounding on the fact that, at one time or other, we are selling out of American or some other foreign securities. This to me is a most unintelligible proof of decline. If I sell out £10,000 of United States bonds and buy an estate, I am not, so far as I know, on the road to ruin. If America buys back her railways, and we buy back ours, I do not see that it makes any difference to either party. But why on earth should we sell our securities, when we do not need to? If, by the figures I have given you, our exports at least balance our imports, surely selling securities besides would be putting the balance heavily on the side of Exports!

This, then, is the reason why we free traders put the emphasis on the figures of Import. There never has been discovered, so far as I know, any means of buying goods but by paying for them. The very fact that we are receiving these imports—that, not the nation, but, the individuals of the nation, every man of them engaged in trading for a profit, are buying these imports,—is sufficient proof that we are paying for them. Nations may run into debt, but, beyond the ordinary terms of credit, the individuals of a nation do not.

But if this is true, mark what follows. It is that all those terrible suggestions about displacement and non-employment of labour are not-proven. You may prove displacement and non-employment by facts—I have not seen the method tried—you cannot by this way of showing that our imports are increasing and forgetting the invisible exports. We are employing the nations of the world in sending us imports; they are employing us in taking our exports. And one thing is certain; that if, by a hostile tariff, you check the imports, you displace those who were making the exports. But this is a displacement of capital and labour which the so called reformers will not condescend to look at.

The Historical Development of the different systems of Education in the Highlands.

By PROFESSOR MAGNUS MACLEAN, M.A., D.Sc., F.R.S.E.

[Read before the Society, 16th December, 1903.]

THE history of Education in the Highlands dates back from the remote period when St. Columba first came to enlighten Northern Alba. To the darkness of paganism among the Picts, and the primitive civilisation still rude and barbarous that obtained among the Scots, he presented what Dr Johnson appropriately called "The benefits of knowledge and the blessings of religion." Like every great reformer, the Apostle of Pictland, believed in the dissemination of learning, and had no sooner established himself in Iona than he set about installing a system of education that for hundreds of years afterwards proved very effective in combating the worst features of the time, and undermining the errors and superstitions of paganism.

The principle on which he proceeded was, that every monastery throughout the country, should be a centre and school of learning. Missionary effort was in every instance to be backed up and re-inforced by scholastic training. It became part of the duty of a bishop in after days to see that the children were instructed. The education so imparted, as we might expect, was based upon the study of the Scriptures. Latin was then the language of the Church, and the studies were no doubt carried on chiefly in that tongue, yet it is to the credit of the Gaelic clergy that they were among the first people in Europe to make their own native tongue a subject of special study.

With the extension of religious houses, therefore, went the gradual spread of instruction throughout the length and breadth of Pictland. For several centuries, as Dr Skene has remarked, there was no Pictish boy taught his letters but received his education from a Columban monk. It was not a universal system of popular training, such as we are familiar with to-day, for it was necessarily limited in scope in days when scholars could not have books of their own, and only a certain percentage of the population was within range and touch of the scholastic work of the monasteries. Still it is a significant fact of history, and one that speaks eloquently in testimony of the industry of the monks, that in 710, little more than a century after St. Columba's death, a knowledge of letters was general in Pictland.

The Norse invasions, not long after, exercised a sinister influence on the progress of education in the Highlands. Nevertheless, the tenth, eleventh, and twelfth centuries saw a considerable increase in the number of schools, such central colleges as Abernethy having apparently several in connection with them. These subordinate schools were mainly under a "rector scholarum," a man of some note and influence, who in turn probably owed allegiance to the *fear leighinn*. The latter, known as lector in English, would seem to have been the ancient *scribhnidh* under another name. As to the chief teacher and lecturer in the monastery, he occupied a place corresponding somewhat to the office of chancellor in the English Church of later times, or of regent in a Scottish University.

A new stage had been reached in the evolution of Highland education when in the reign of Malcolm IV. (1153-1165), burgh schools such as those established in Perth, Stirling, and other Scottish towns began to come into existence. It is characteristic of these that they were the first to appear separate from religious institutions. Formerly education seemed to have been wholly in the hands of the Church. Now it had developed so far, that to a certain extent it could maintain itself apart from direct ecclesiastical control.

Not much is known of the scholastic situation within the Celtic fringe, during the next three hundred years, as there are so few native documents to throw light on the subject. But shortly before the Reformation, Bishop Elphinston of Aberdeen, most laudably exerting himself in the interests of education, procured a papal bull for the foundation of King's College in that city in 1494. This enterprise had the sanction and co-operation of James IV., as may be inferred from the name. The buildings were completed in 1500, and it is noteworthy that the scheme had for its chief motive the extension of learning and civilisation throughout the Highlands. At the Grammar school which in common with the College of Aberdeen, afterwards drew many students from Celtic districts, Gaelic was one of the languages, including Latin and French, in which the scholars were permitted to converse in the building, though the Lowland Scotch, it is now strange to think, was then forbidden.

Government had by this time begun to take an interest in the national education. In 1496 while the College was in process of construction, Parliament passed an Act requiring all barons and freeholders, under a penalty of twenty pounds, to send their sons at the age of nine to schools, where they were to be taught Latin, and afterwards to remain three years at the schools of "Art and Jury." This looks like the first attempt at compulsory education, though Dr Hill Burton thinks it was hortatory, rather than legislative. In any case few of the Highland chiefs appear to have appreciated the good intentions of the authorities, or given heed to this minatory exhortation.

A remarkable feature of that pre-Reformation period was the institution of "Song Schools." At first the experiment was confined to Cathedral towns and designed for choir training in the Church services. Its success led to a wider diffusion which gradually extended the advantages to young people generally. After the Reformation other subjects were taught in not a few of these schools, and the original idea has survived in a modified form to the present day. It is recorded that so late as 1733, the salary of a teacher of singing was found as one of the charges against the revenues of the royal burgh of Tain in Ross-shire.

Such was the stage the progress of education in the Highlands and in Scotland generally, had reached, before the Reformation opened a new chapter in our history. It is popularly supposed that a fully equipped school system came into existence with the establishment of Presbyterianism and the advent of Knox. This is not strictly true. John Knox was certainly a potent force in this direction, like his distinguished precursor, St Columba, a thousand years before him; but the Reformer's enlightened proposal to have a school in every parish in Scotland was not realised for many years after. As Mr Lang has indicated, his efforts in favour of education were too far in advance of his age to be entirely successful. In the Highlands especially, the influence of the Renaissance, and of the Reformation was not much felt. The Highland barons, following the example of their Lowland contemporaries, seized the revenues which Knox designed for the support of education, and though many schools were established in the northern counties by commissions of the General Assemblies, quite a number of them soon disappeared, owing to isolation from the central authority, and local hostility and neglect.

But by this time the question of national education could no longer be shelved. The more school work was frustrated the more pressing and clamant the need of it appeared in the eyes of the governing authorities, and as soon as one effort failed another was tried.

James I. of England in particular interested himself in the matter, and some of his measures proved eminently wise and beneficial. As early as 1609 he had the subject of education in the Western Islands dealt with by an Assembly at Iona of Hebridean notables, not very willingly brought together under the presidency of Andrew Knox, Bishop of the Isles, who was backed by sufficient naval and military force. Besides the President there were present at that famous gathering Angus Macdonald of Dunyvaig, Islay; Maclean of Dowart, Macdonald of Sleat, Macleod of Harris, Macdonald of Clanranald, Maclean of Coll, Mackinnon of that ilk, Maclaine of Lochbuy, Lachlan and Allan, brothers-german of Dowart, Macquarrie of Ulva, Macfie of Colonsay, "togidder with the maist part of thair haill special freindis, dependacis and tennentis compeir and judiciallie." The measures they passed are still known as the "Statutes of Icolmkill." Of these the sixth provides "that every gentilman or yeaman within the saidis Islandis or any of thame having children maill or famell and being in goodis worth thriescoir kye sall putt at the leist thair eldest sone, or having no children maill, their eldest dochter to the scuillis in the lawland, and interteny and bring thame up thair, quhill they may be found sufficientlie to speik, reid, and write Inglische."

In this mandate it appears that the education of the daughters of chiefs and chieftains only became compulsory when there were no sons, the general impression being at that time that it was neither necessary nor desirable to educate the girls. Thus Martin in his history of the Western Isles makes the interesting statement that "women were anciently denied the use of writing in the Islands to prevent love intrigues; their parents believed that nature was too skilful in that matter, and needed not the help of education; and therefore that writing would be of dangerous consequence to the weaker sex."

These were the days when matrimony was regarded as the one chief object in the life of a girl, and though the order in the above Act was made, seven years later, to include all the children of such families over nine years of age, the education of girls was more or less neglected among the peasantry of many parts of the Highlands till well on in the nineteenth century.

The effect of the above representative, and in a manner self-imposed measure, appears to have been good. Many have attributed to it the great change that took place some time after in the feeling of the Highland chiefs towards the Stuart Kings. It is thought that it was those who were thus educated who adopted the new attitude.

The "Statutes of Icolmkill" were, in 1616, followed up by an Act[1] of the Privy Council on similar educational lines. It practically made the provisions compulsory; indeed, this act may be regarded as the first compulsory one so far as the Highlands was concerned. In the preamble the "continewance of barbaritie, impietie and incivilitie" within the Isles is attributed to the neglect of education, particularly as the children were not sent in their youth to the mainland to be trained in virtue, learning, and the English tongue. It was therefore enacted that all the chiefs and principal clansmen send their "bairnis," when upwards of nine years of age, to the inland schools to be so trained. It was further enacted that "no personis quhat somevir in the yllis sal be seruit air to thair father or ytheris predicessouris nor ressauit nor acknawlegeit as tennentis to his Maiestie unless they can write, read, and speak Inglische."

Later in the same year an Act[2] was passed for the establishment of parish schools in Scotland. And here the unwisdom of King James VI. and his advisers, with reference to the treatment of the Highland vernacular comes out, for among the objects aimed at was the extinction of Gaelic, one of the provisions of the Act being—"That the vulgar Inglish toung be vniversallie plantit and the Irishe language which is one of the chief and principall causis of the continewance of barbaritie and incivilitie amongis the inhabitants of the Iles and Heylandis may be abolisheit and removeit."

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This policy of extinguishing the language of the people in the schools, initiated then, has, except in rare cases, been followed almost down to the present time, and has been held by those most competent to judge, to have been most hurtful to the intelligent education of the Highland people, and even to the progress of the English language in the country.

For the next hundred years after the establishment of the parish schools, very little is recorded of exceptional interest. These schools held the field. One in each parish, which was the aim rather than the accomplished fact, was ridiculously inadequate, but there seemed to have been hardly any attempt to supplement them, much less to usurp their rights and functions, which were jealously guarded. About the middle of the seventeenth century a lady from Morayshire ventured to open a private school in Inverness. In consequence, the magistrates met to consider the innovation which they thought trenched on the vested rights of the parish schoolmaster. They did not go the length of ordering her to shut up the establishment, but they enjoined her not to teach beyond the Proverbs, which, with the Book of Psalms, were considered the elements of school training.

Meanwhile, the scholastic accomplishments of the middle and upper classes had developed apace. They not only received a regular education at local grammar schools, such as those of Inverness and Aberdeen, but they were sent to the universities, and many of them abroad to Bruges, Leyden, Douay, and other Continental towns. Nor was the education of the girls neglected, as may be seen from the Kilravock and other papers of the period. In fact, Dr Johnson found a high degree of culture among this class when he travelled in the west, and was astonished at the number and quality of the books they possessed. It is even recorded that many Skye gentlemen spoke Latin better than English, and one traveller at least mentions the fact that when the Hessian troops were quartered in Athole, in 1745, the officers found the Roman tongue a ready means of communicating with the innkeeper.

Thus it fared with the well-to-do, but not with the common people. By the year 1696 it became evident that there were not schools in every parish, that in fact many places were utterly destitute of the means of education, and a new Act was framed authorising "that there be a school settled and established, and a schoolmaster appointed in every parish not already provided, by advice of the heritors and minister of the parish," and fixing the rate of salary to be not less than 100 merks, and not more than 200.

It was utterly impossible, however, that this parochial system could meet the wants of the leviathan parishes of the Highlands. The parish of Harris included outside its own rugged boundaries, as many as seven other islands, not to speak of St. Kilda, with its interesting ferry of fifty miles. Of what account would one school be to this scattered area? It is enough to mention, among others, Lochbroom, Gairloch, Lochalsh, Glenelg, Ardnamurchan, Lochs, South Uist, Kildalton, Jura, each of extent sufficient to make a county considerably larger than Clackmannan or Kinross. The defects of the public educational provision, as in these instances, began to be recognised. The parish schools, though admirable in their own way, did not and could not overtake the work in the Highlands, and from this period dates the gradual establishment of the non-parochial schools.

A new era of private enterprise had really opened—a new departure in the development of Scottish education had been inaugurated, when at the beginning of the eighteenth century the Society for Propagating Christian Knowledge came into existence. It was the first of the kind to undertake the work of providing schools for the poor and neglected areas.

This most useful Society had its origin in the design of a few private gentlemen, who met in Edinburgh in 1701, with philanthropic, missionary, and scholastic aims. Their first school was started at Abertarff, which, in the words of the records, was "the centre of a country where ignorance and popery did greatly abound." The teacher, in this case, was harshly treated by the people, and in less than two years was obliged to leave the parish. Though no successor to him was appointed, the Edinburgh philanthropists went on to plant schools in other parts of the Highlands. They secured the co-operation of the General Assembly of the Church of Scotland, collected money throughout the kingdom, and in 1709 obtained letters-patent from Queen Anne erecting certain of their number into a Corporation, under the title which has become so well known. By decree of the Court of Session, the Society is now inseparably connected with the Established Church. Its capital, which in 1708 was £1,000, had amounted in 1781 to £34,000, and by that year the schools numbered 180, with an attendance of 7,000 scholars.

Mr Boyd, the present chief inspector of schools in the Aberdeen district, thus gives his impression of the Society's work. "Its administration was enlightened and beneficent, its encouragement, pecuniary and otherwise, of promising scholars being an admirable feature, and it supplemented the statutory school supply, which was still very imperfect, with equal liberality and discretion. The directors, accepting the common view that the prevalence of the Gaelic language was one of the causes of the existing evils in the Highlands, at first forbade instruction in that language, but afterwards the teachers were enjoined to teach the meaning of the English lessons, and ultimately Gaelic books were circuculated, an edition of the New Testament in that language, being prepared at the Society's expense. The teachers, not a few of whom were men of university education, had to be duly examined, and on passing successfully were awarded a formal diploma. They received fixed salaries, and were not to exact fees. Sometimes the schools were endowed with 'crofts' by proprietors who sympathised with the Society's aims. Shortly before the middle of the eighteenth century, the Society made a notable attempt to establish technical schools. The agricultural schools failed, and the attempts to start linen manufactures, as at Lochcarron and Glenmorriston, met with small success. Spinning schools, however, in which various home industries were taught, were maintained for many years in various localities."

It is worthy of note that in its palmy days some of the most distinguished poets of the Highlands were teachers in the service of this Society. Alexander Macdonald, Dugald Buchanan, and Ewen Maclachlan, all had a share in its work. The salary was not great, ranging as it did from £10 to £20, but it must be remembered that from 1696 to 1803, the highest statutory salary of the parochial schoolmaster in Scotland was only £11 2s. 2⅔d. per annum, payable half yearly, and the lowest, half that sum.

Even with the help of the S.P.C.K. the supply of schools throughout the Highlands was lamentably deficient. After the rebellion of 1715, Parliament voted £20,000 for additional education, and commissioners, in a report to the Secretary of State named 151 places where schools were needed, but with the report the matter seems to have ended.

King George I., however, in 1725, gave a donation of £1,000 to the General Assembly of the Church of Scotland "to be employed for the reformation of the Highlands and Islands, and other places where popery and ignorance abound," And this gift, which was annually continued by the king and his successors, was placed under the control of a committee nominated by the Assembly and called "The Committee for managing the Royal Bounty." This committee have usually co-operated with the Society for Propagating Christian Knowledge, and shared its burdens.

Meanwhile, the stormy period of the Forty-five intervened, and we hear little of education except in so far as the existing agencies were unobtrusively at work, till the beginning of the nineteenth century, when another Act was passed (11th June, 1803), "for making better provision for the Parochial Schoolmasters, and for making further regulations for the better government of the Parish Schools in Scotland."

From this time the voluntary effort began to broaden out, and a variety of new agencies gradually came into existence, which resulted in a vast increase of the non-parochial schools.

First there was the Gaelic School Society, formed in January, 1811. The resolutions adopted at its inception acknowledged the great services rendered by the S.P.C.K. in promoting civilisation and religious knowledge in the Highlands, but deplored the lamentable fact that many parts of that region were still in a state of great ignorance, and that only a small proportion of the inhabitants could read in any language. It was agreed that the cheapest, most expeditious and effective method of dealing with the situation would be the erection of circulating schools for the express purpose of instructing the people in the Gaelic language, and that the only object of the Society should be to teach the inhabitants to read the Holy Scriptures in their native tongue.

On this basis the Society has unquestionably conferred great benefit on the Highlands and Islands. It was objected against its system at first that it would retard the spread of the English language, and thus militate against the progress of the North; but it has been found, on the contrary, that the Gaelic schools have very materially contributed to awaken a genuine desire for education among the people. Recognising this, the Society afterwards so far modified the original constitution of the schools that they authorised their teachers to impart a knowledge of English to the pupils as soon as they had learned to read in Gaelic.

The number of these schools in 1865 was forty, all but ten in the Hebrides. They were transferred as a rule from one place to another every three years. The salary was £25 a year. No fees were charged, but a house was provided by the people of the district, sometimes by the proprietor. The buildings were thatched cottages, seldom better than the local dwellings around; and though it was one of the original rules of the Society that the teachers should neither be preachers nor public exhorters, this rule was not rigidly enforced, for in remote districts they usually conducted a religious service on Sundays. The schools were visited once a year by an inspector employed by the Society.

In 1824 the directors of the S.P.C.K., after careful enquiry, came to the conclusion that great injury had been done by the general neglect of the vernacular language in the work of education in the Highlands, and resolved henceforth to encourage it. As a result, they had a set of new lesson books prepared, and made it a rule that the children should be taught to read Gaelic first before being taught English.

Next year, 1825, another important and useful class of schools was established. These were known as the General Assembly Schools, of which, in the course of forty years, there were altogether about 200 throughout Scotland, twenty-nine of them in the Hebrides. The following was the system adopted. The heritors supplied the site and buildings for school and school-house, providing also a croft for the teacher, or money equivalent, and the General Assembly gave sums varying from £5 to £25 in lieu of salary, keeping the appointment of the teacher and general superintendence of the education in their own hands. Most of the schools so provided were under government inspection.

By the year 1838 Parliament had again awakened to the fact that the parish schools, and other means of instruction existing in the Highlands and Islands, were wholly inadequate to the needs of the people. This was borne in upon the legislators, particularly by the recent erection of quoad sacra parishes, demanding the endowment of additional centres of education if there was to be a school in each parish. A new Act was therefore passed providing for quite a number of side schools over and above the parish schools already in existence.

In 1843 an event occurred which affected still more intimately the educational machinery of the Highlands. This was the Disruption of the State Church, which culminated in the formation of the Free Church, which for half a century afterwards dominated the religious life of the North. No sooner had the divergence taken place, than the new denomination set about establishing schools of its own. The result was that not a few of the teachers who originally held parochial, General Assembly, or S.P.C.K. school appointments, transferred their allegiance to the younger body, and became masters in the Free Church congregational and district schools. In the circumstances, a certain amount of rivalry and competition was inevitable, but it appears to have been on the whole more stimulating than hurtful.

These newly-appointed schools, under the charge of a committee of managers connected with the congregation of which the minister was always the chief member, were mostly in the northern half of Scotland. Indeed, the Parliamentary Education Commission of 1865, found that in the counties of Ross and Sutherland nearly half the education seemed to be carried on by means of Free Church money and influence. The appointment of the teacher lay virtually with the local minister, who superintended the work, and as the Free Church education committee had no inspector of schools, those of the latter that were not under government inspection were regularly examined by the local presbytery on the same system as that followed in the Established Church, and a report was sent once a year to the committee in Edinburgh. Most of the teachers were very inadequately paid, though some in better favoured districts received very respectable incomes. The funds seem to have come from collections for educational purposes raised throughout the Church, and distributed by the committee, the ordinary annual allowance for each school in the Hebrides being £12. In addition, there were at the disposal of headquarters, Privy Council grants, which certain of the schools earned, and the interest of the Maclaren Bequest of £7,000, with any other legacies and donations that accrued as the work of the Church developed. Fees were also invariably charged.

Closely connected with these educational organisations of the two churches existed other two agencies, carried on on a different footing, under the titles the Church of Scotland Ladies' Association Schools, and the Free Church Ladies' Association Schools.

The first of these Societies was founded in 1846 for the purpose of supporting or aiding education in destitute Highland localities. Reading in the native Gælic was wisely regarded as of primary importance to such children as understood no other language; but English was taught in all the schools, while in some of them the instruction was as comprehensive as in any of the neighbouring scholastic resorts. The number of teachers supported wholly or partially by the Society in 1865 was 34 at a cost in salaries of £645 per annum. Of these schools, there were 10 in the Hebrides; all except 3 conducted by female teachers. None of them was maintained exclusively by the Ladies' Association; for some had connection with the General Assembly, or S.P.C.K.; while others were partially supported by subscriptions of proprietors and others interested. The usual salary was £20 a year; but the Society encouraged the taking of fees where they could be got.

The second of the Societies above mentioned, namely, the Edinburgh Free Church Ladies' Association for the Religious Improvement of the remote Highlands and Islands was formed in 1850, for two special objects, viz., (1) to increase aid-schools in destitute Highland districts, and (2) to assist promising young men in prosecuting their studies for the ministry. In 1865 there were no less than 55 such schools, taught chiefly by students in the summer months, who supplied local substitutes during the winter when they were absent themselves at College. Of the above number 40 schools were in the Hebrides, the rest scattered over the Highland mainland. In the majority, provision was made for the teaching of sewing, and in many instances the Association supplied clothing for the poorest of the children. No fees were charged, but the inhabitants were expected to provide the buildings and to contribute a few pounds annually to the funds of the Association. In most places they generally contributed something also in other ways to the teachers' support. The buildings were usually of the poorest order, and the substitute who acted in the winter, being merely a youth from the district, or one of the senior pupils of the school, could not be expected to give the same efficient service as the university student, though the school during his term had generally its best attendance. Yet the system proved very helpful in the remote districts.

supplied, and the schools did not always suffer very much by the annual change.

The teachers received a salary of £20, half of which they paid their substitutes, and in addition to this, each student-teacher got £10 every session to assist him in his college studies; so that as an agency the Society was effective in providing means for the promotion, on a small scale, both of the lower and higher education.

These appointments were certainly beneficial to many aspiring Highland youths, enabling them to proceed to the university, and even preparing them for their future work in the ministry, since not a few of them exercised their talents in conducting occasional religious services.

A Glasgow Free Church Ladies' Association, having the same objects in view, was founded two years later, but it was afterwards affiliated with the Edinburgh one.

In addition to all these kinds of schools, there were three other classes that had been gradually springing up in the towns and more populous centres. These were, (1) The Subscription schools maintained either by proprietors and other persons interested in particular localities, or by the inhabitants, and worked independently of the denominations and societies above mentioned; (2) the private adventure schools, of which there are a few, chiefly in the towns; and (3) the endowed schools still more rare.

Most of the academies, collegiate institutions, and secondary schools that fall under one or other of these categories in the Highlands, have been established during the course of last century, and are now under government inspection and in receipt of State aid, as are also the Roman Catholic schools that subsequently came into existence.

Another important step forward in the evolution of national education was taken in 1861, when the Parochial and Burgh Schools Act was passed. Some of the more beneficial provisions of this measure were these: (1) The examination of parochial teachers was transferred from the Presbytery to a qualified body of examiners consisting of six university professors. (2) The schoolmasters were no longer required to sign the Confession of Faith, or Formula, but to make a declaration and to undertake to conform to the Shorter Catechism. In fact, in the case of the burgh school teachers absolute freedom was given on this score. "From and after the passing of this Act," the measure went on to say, "it shall not be necessary for any person elected to be a schoolmaster of any burgh school to profess or subscribe the Confession of Faith, or the Formula of the Church of Scotland, or to profess that he will submit himself to the government and discipline thereof, nor shall any such schoolmaster be subject to the trial, judgment, or censure of the presbytery of the bounds for his sufficiency, qualifications, or deportment in his office, any statute to the contrary notwithstanding." (3) Jurisdiction in cases of immorality were transferred to the sheriff. (4) A method of procuring resignation from superannuated teachers was introduced. (5) Female teaching was sanctioned, giving rise to heritors' girls schools. (6) The salaries were raised. They were from this time to be not less than £35 nor more than £70 per annum, but where there happened to be two or more schools established in the parish, the total amount of the salary payable to the schoolmaster was not to be less than £50 nor more than £80, to be apportioned among them as the heritors should determine, in the manner provided by the Act.

So far so good; but it soon became evident that this could only be a temporary measure, for the circumstances of the country were fast changing and really demanded a brand-new system of education. No tinkering at the old methods would much longer suffice. Accordingly, a Royal Commission on Education was appointed, and in 1865 the Assistant Commissioners, Mr A. C. Sellar, M.A., and Lieut.-Col. C. F. Maxwell were authorised to enquire into the state of education in the country districts of Scotland. They gave in their report next year along with another bearing on the Hebrides by Assistant Commissioner, Alexander Nicolson, M.A., Advocate, and both were presented to Parliament. It is evident from these documents that the country was ripe for a change, and that a real national system of education, which would supersede the multitude of struggling agencies at work that were still far from adequate, was much needed. The investigation revealed a lamentable backwardness and inefficiency, not only in many State-aided schools, but also in not a few of the voluntary ones.

The standard demanded by the country had changed, and what was deemed good fifty or a hundred years before was now no longer regarded as satisfactory. Speaking of the S.P.C.K.

schools in the Hebrides, Mr Menzies, a former inspector of the Society stated in evidence before the Education Commission that " the education in them was of a very low character indeed," a report which Mr Nicolson corroborated. And this is only one instance of the conditions that were more or less prevalent throughout the country—though there are exceptions to every rule, and some schools of Scotland produced a number of excellent scholars.

The buildings in particular at that time were very inferior, and scarcely half the population, especially in the Highlands, were efficiently educated. In 1862 the percentage of men in the Hebrides that signed their names by mark in the marriage registers was 47.6. and of women 64.8. There was as yet no legal compulsion of attendance at school, and consequently the Commissioners found, in 1865, that in 133 parishes or districts of Scotland which they visited, less than half the number of children between three and fifteen years of age were in school. In Easter Ross the percentage of those who did not attend they found to be 55. And it is curious now as we look back from the short distance of less than 40 years, to read the candid opinion of these experts relative to the subject of compulsion, which was just beginning to be mooted. "It is hazardous," they reported, "to express any decided views upon the question of compulsion, direct or indirect, in the present uncertain state of education. The difficulties lie in the public feeling against all restrictive measures, and in the expense and organisation necessary to establish the machinery to carry them out. If compulsory education is ultimately to be established, the process must be gradual, and public opinion must be prepared to see the necessity of it. At present the opposition to such a system would be invincible."

This was the stage reached by enlightened opinion on the subject when the great Act of 1872 was passed, revolutionising education in Scotland and putting it upon an entirely different basis. From this time the bogey of compulsion gradually disappeared, for it became legally imperative to educate children of school age. The former Acts of 1696, 1803, 1838, and 1861, were repealed; the need for separate denominational schools passed away, and a great unification in the general system of education was effected whereby the ecclesiastical control of education in Scotland, which had lasted for 1,200 years, finally came to an end.

Among other striking signs of the new order were the creation of a Scotch Education Department, the formation of triennial School Boards, and the erection of large and commodious school buildings all over the country, for which grants were provided. Nowhere was the contrast between the new and the old more marked than in the Highlands, where the houses that so frequently did duty as schools, were often deplorable. As the Crofter's Commission subsequently observed, the visible effects of the Act in this respect were "almost as remarkable as the state of the Highland roads after they were constructed by Marshal Wade." "If the design has been in some cases unnecessarily costly," they added, "not to say extravagant, the advantage from an educational point of view, of accustoming the children of the poor to rooms which are patterns of cleanliness and order, cannot be reasonably questioned. The more they are impressed by the contrast between the tidy comfort of the schoolroom, and the rude poverty of their homes, the more likely are the dwellings of the next generation to be improved." This was a shrewd prediction which has already largely been fulfilled. The change in the housing of the Highland peasantry since the passing of the Education Act, and the work of the Crofters' Commission has been simply phenomenal—and could scarcely be credited twenty years ago.

At the same time a result which was certainly not contemplated by the framers of the Scotch Education Act, created a difficulty in the Highlands. This was the exorbitant school rate in some of the insular parishes. In the parish of Barvas, Lewis, in 1881, it reached the extraordinary maximum of 6s. 8d, in the pound; in Harris, the following year it was 2s. 8d., and in North Uist, 3s., though in the Lowlands it did not exceed, as a rule, a few pence.

Indeed the immediate effects of the Education Act in the Highlands were by no means salutary, for there was necessarily much delay in many parishes in the erection of the new buildings, and meanwhile the schools that used to be kept up by ecclesiastical agencies or benevolent societies were being abandoned. Hence arose a temporary paralysis of educational effort which unmistakably affected adversely in many places the interests of the rising generation. Generally speaking, the Crofters' Commission found that the benefits of the Act did not, for several years after its passing, come fairly into operation in the Highlands and Islands, and they had several useful recommendations to make to the Education Department. For one thing they urged that all rating above 2s. in the pound should be paid by Government; for another, that the building debts should be cancelled; and for a third, taking into account the difficulties of attendance at school in these poor and remote regions, they recommended that the number of days qualifying for the grant should be reduced.

As one result of their report, Mr Mundella sent Dr Craik to the Highlands in September 1884, to investigate. The Commission had called attention to the low attendance, and the causes of this he found not only in the natural difficulties of the country, distance from schools, bad roads and bridges; but also in the circumstance of the parents' poverty, appearing in want of clothes, food, and fees, as well as in their need of the children for herding and other work. There was over and above some apathy and even hostility to education. Attendance, he urged, must be enforced for the money returns and the education dependent upon it, He did not see his way to fall in with the recommendations of the Commission regarding the rates and building debts, but he suggested a considerable increase of grants. For fostering secondary education he recommended the employment of a graduate in one school in each district with special facilities for teaching and gaining higher grants for the higher standards and subjects.

With regard to the teaching of Gaelic, considering every view candidly, he arrived at the conclusion that it ought to be taught to the junior children whose mother tongue it was, and might be taught to the senior children as a specific subject.

After the department deliberated over these points, a Highland Minute appeared early in the following May, making important additions to the Code in regard to the Highlands, and generally giving effect to Dr Craik's suggestions.

The new regulations set forth that in these parts, burghs excepted, if a school made an average attendance of 65 per cent. for the year, taking as basis the number on the roll at the year's end, the average attendance grant would be raised from 4s. to 5s. per head, for 70 per cent. to 6s., for 80 per cent. to 8s., the double of the original sum and the maximum obtainable.

Secondary education received a powerful impetus through the concession that if central schools were established, each under a graduate, with time for extra work, by only having 30 pupils allotted him in average attendance, 10s. would be given for each pass in specific subjects, instead of 4s. as in other parts of Scotland.

In regard to the teaching of Gaelic, Gaelic-speaking pupil teachers might be employed for the infants and junior children. Such teachers would be recognised and paid the P.T. grant, even though the numbers in the school did not entitle them to this payment; and further, the P.T. would be allowed to spend the last year of his apprenticeship at a preparatory school for entrance to a training college. For each infant thus taught by Gaelic P.T.'s 10s. was promised, and for the upper classes Gaelic was made a specific subject like Latin or Mathematics.

It is interesting to note that in the discussions held at teachers' meetings in various places in connection with this Highland Minute, the fact was brought out, that only 50 per cent. of the children on the roll in the Highlands were in average attendance, so that to gain even the first additional shilling, a leeway of 15 per cent. had to be made up. Yet it gave the local boards a stimulus, and matters are now on a much better footing.

In 1888, in view of an impending financial breakdown in the Hebridean parishes of Barvas, Lochs, and Uig, and certain other Highland districts, the Education Department adopted a further Minute whereby these places were to receive exceptional assistance, and a representative of the Department, Mr J. L. Robertson, H.M. Inspector of Schools was associated for this purpose with the local administrative authorities. This arrangement has proved eminently successful.

Later, under the Local Taxation (Customs and Excise) Act, 1890, and the Education and Local Taxation Account (Scotland) Act, 1892, the State-aided Schools of Scotland were relieved from the payment of school-fees, and Town and County Councils were empowered to contribute to the support of technical instruction. The result has been a broadening out of secondary education not only throughout the Lowlands, but all over the Highlands where secondary centres have been established. In connection with these and the establishment of the evening schools, subjects of Science and Art have been taught, chiefly in the towns, where the schools for higher education are most in evidence.

A prominent feature of the new education in the North as elsewhere, are the classes established by the County Councils for instruction in cookery, laundry and dairy work, as well as in commercial education, and the lectures delivered on subjects of agriculture, ambulance, and sanitation.

Under the new Code of 1900, a further advance has been made towards the realisation of a still more rational system of education; and if the proposed new legislation is carried, we may expect a change in the near future as drastic and beneficial as any that has taken place within the last half century.

A long way has the country advanced since St. Columba first planted his monasteries and opened his schools. Doubtless it was the early impetus thus given and the work carried on so faithfully by the Church till the State finally relieved it of all further responsibility in the matter, that helped to keep Scotland so far in advance even of England, more than half of whose schools are still under ecclesiastical authority and clerical sway.

Among the good things that education has brought the Highlanders, are a knowledge of English, wider social and political interests, a brighter intelligence and brighter outlook, freedom from mental vacuity and traditional superstitions. In fact, it has introduced them into a new world of life and thought from which if the ancient tongue is largely excluded, so also are the fairies, the second-sight, the water kelpie, the brownie or gruagach, the corp criadha, dead-lights, witchcraft, and the evil eye; and from their condition under the depressing circumstances that prevailed even fifty years ago, the Scottish Gaels have been transformed in the main into a much more industrious, contented, and happy people.

Experiments in Radio-Activity.

By H. Stanley Allen, M.A., B.Sc.

[Read before the Society, 18th November, 1903.]

Part I.

In a paper which I had the honour of reading before the Mathematical and Physical Section of the Society during last Session I gave a short account (*Proc*, vol. 34, p. 107, 1903) of the modern theory of Ions or Electrons.[1] Perhaps I may be allowed to refer once more to this theory, as the results which I have to bring before you to-night are most easily expressed in terms of it. On this view electrical conduction through a gas is similar in character, though not in degree, to conduction through a liquid. The molecules of a gas, which under ordinary conditions are electrically neutral, can be split up by appropriate forces into positive and negative ions. It is the passage of these ions through the gas which constitutes the electric current.

Our knowledge of the discharge of electricity through gases has been largely increased by the study of the discharge when the pressure of the gas is greatly diminished—that is in so-called "vacuum-tubes." I hope to be able to show you some of the beautiful experiments devised by Sir William Crookes many years ago, experiments which possess additional interest to-day as they show us effects in many ways similar to the effects produced by radio-active substances.

(A number of tubes were exhibited, illustrating the stages passed through as the pressure of gas in the tube is diminished, and the production of kathode rays when a high vacuum is obtained. It was shown that these rays travelled in straight lines from the kathode and were capable of exciting fluorescence in various substances on which they fell. The deflection of the kathode beam by a magnetic field was shown by means of a tube containing a fluorescent screen set at an acute angle with the path of the rays, in such a manner that the track of the beam was marked by a line of light. It was pointed out that by measuring the deflection of the rays in a magnetic and electrostatic field it was possible to determine the ratio of the mass of a corpuscle to the charge which it carried, assuming the kathode beam to consist of a stream of negatively charged particles projected with great velocity).

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[1] In the paper on Ions I referred to the controversy as to whether a moving electric charge possesses the power of deflecting a magnetic needle, and mentioned the contradictory results obtained by Crémieu and by Pender. Since that paper was written the explanation of the apparent contradiction has been given by these experimenters, who, on the initiative of M. Poincaré, have carried out a joint investigation at the Sorbonne. They conclude that a charged continuous metallic disc turning in its own plane opposite fixed condensing plates, carries its charge with itself, and that the movement of this charge produces a magnetic field in accord with the theoretical value. Also

We have read so much of radium and its powers in scientific papers and the public press that some of us feel in difficulty. We hardly know what radium can *not* do, or perhaps we have become sceptical of its power to do anything. In the present paper I shall confine myself for the most part to facts observed and experiments carried out at Blythswood. Some of the properties of radium I hope to be able to show you by actual experiment, but in many cases the apparatus required is so sensitive that it is impossible to show the results to an audience, especially when the supply of radium is limited.

It is necessary that at the outset I should give some account of the discovery of Becquerel radiation and of the history and preparation of radium. In 1895 Röntgen discovered the rays which have made his name famous. These rays as we now know originate at the place where the kathode stream impinges on a solid obstacle, but at that time it was thought that they might be connected with the fluorescence of the glass. This led Becquerel to the study of the fluorescence of uranium salts, and

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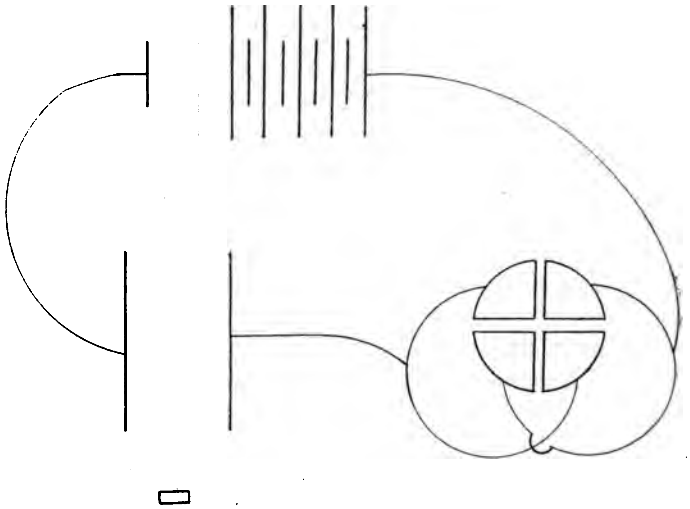
charged sectors moving in their own plane produce a magnetic effect that accords with theory.

It is I think a striking sign of the spirit that animates scientific workers, that two investigators, of different nationalities, having obtained opposed results, should have so joined forces and worked side by side towards a definite solution of the question at issue. As Lord Kelvin, at whose suggestion Paris was chosen as the most favourable place for these experiments, remarked recently at Cardiff, "Scientific men recognise as fellow-countrymen workers in science over the whole of the habitable part of the earth."

at the commencement of the year 1896 he observed that the salts of uranium "emitted an invisible radiation, which traversed metals and bodies opaque to light as well as glass and other transparent substances. This radiation impressed a photographic plate and discharged from a distance electrified bodies—properties giving two methods for studying the new rays." (*Nature*, 63, p. 396, 1901.)

Becquerel at first generally employed the photographic method, but the electrical method possesses great advantages both in delicacy and in the rapidity with which observations can be made.

The principle of the electrical method may be readily understood by means of the diagram.



Of two parallel metal plates one is connected to the insulated pair of quadrants of an electrometer, the other is connected to one pole of a battery. The other pole of the battery is connected to the remaining pair of quadrants, and also to "earth." In ordinary circumstances no charge, or at most a very small one, can leak across the air space between the metal plates, but if the air is subject to Röntgen or Becquerel radiation, its conductivity is increased, an electric current will pass and gradually charge the electrometer. By noting the rate at which the electrometer needle moves we can estimate the "rate of leak" of electricity across the gap.

In order to realise the sensitiveness of the electrical method of examining these effects we must remember that in general a gas is an almost perfect insulator, provided the intensity of the electric field is less than a certain critical value. In hydrogen, for example, a spherical conductor can receive a charge as great as 9 electrostatic units per unit area without discharge taking place. J. J. Thomson has pointed out that if electric conduction in gases were of the same order as conduction in liquids one c.c. of hydrogen would be able to carry 3×10^{10} electrostatic units. That is to say, it would only require 3×10^{-10} c.c. to carry off the charge from each unit area of the sphere. We see how very small is the quantity of hydrogen that would be required to remove the charge, and yet as a matter of fact only an exceedingly small fraction is lost through gaseous conduction. If this had not been the case, and the atmosphere had been even a feeble conductor, it is probable that we should at the present day be almost entirely ignorant of electrical effects.

Shortly after Becquerel discovered the radio-activity of uranium, Mme. Curie made an examination of a large number of elements by the electrical method and found that another element—thorium—was also radio-active. She also observed that certain minerals containing uranium and thorium were more active than these elements themselves. These observations led to an exhaustive inquiry by M. and Mme. Curie into the composition of pitch-blende, and ultimately to the discovery of two radio-active substances "polonium" and "radium."

Pitch-blende is a somewhat rare mineral found in Cornwall, in Adrianople, in Bohemia, and some other localities. About 75 per cent. of it consists of oxides of uranium (U_3O_8). Radium is only present in traces, and the Cornish mineral, a sample of which is before you, is said to contain even less than the foreign ores.

The ore is roasted with carbonate of soda and then treated with sulphuric acid, which removes the uranium in soluble form. The separation of radium is based on the fact that the sulphate of radium, which in its chemical behaviour resembles barium, is extremely insoluble. A mixture of the sulphates of barium and radium is obtained, and the sulphates are converted into chlorides. From one ton of ore only about 15lbs. of the mixed chlorides is obtained, and of this quantity only a small fraction is pure radium chloride. The radio-active salt is separated from the inactive barium by a process of fractional crystallisation. In this way M. and Mme. Curie, using the electrometer as the chemist would use the spectroscope, succeeded in isolating radium —an element which was found to possess a definite spectrum and an atomic weight of 225.

Before attempting to summarise the properties of radium it may be well to draw attention to the fact that, in speaking of "rays" and "radiation" in this connection, we do not mean to imply that what takes place is similar to what we suppose takes place in the case of ordinary light. These terms are found convenient to designate an effect propagated with great velocity in a straight line. We are already familiar with such a usage in speaking of X rays (aether pulses) and kathode rays (streams of corpuscles).

The rays emitted by radio-active bodies are not all of the same kind. They are distinguished from one another by differences in penetrating power, and by the effect upon them of a magnetic field. They may be divided into three classes—

α Rays. These are rays with little penetrating power, they are responsible for a very large part of the conductivity imparted to a gas. A very strong magnetic field is required to deflect them. From the effect observed it is concluded that they are positively charged bodies, comparable in size with a hydrogen atom.

β Rays. These are identical with "kathode rays," that is to say, they are negatively charged particles projected with great velocity, and they possess an apparent mass about one-thousandth part of that of the hydrogen atom. They are far more penetrating than the α rays.

γ Rays. These are very penetrating rays, not deviated by a magnetic field. Their properties have not as yet been thoroughly studied, but it is possible that they are similar to X-rays.

The properties of radium (and other radio-active elements) may be considered under the following heads :—

1. Electrical effects.
2. Production of Fluorescence.
3. Photographic effect.
4. Heating effect.
5. Production of "emanation" and "excited activity."
6. Physiological effects.

1. The electrical effects have already been referred to, and more is to be said about them in the second part of the paper.

The discharging of electrified bodies by the action of the radium rays may be illustrated by the discharge of a small gold leaf electroscope (projected upon the screen).

2. A large number of substances become fluorescent under the influence of the rays of radium. A screen of platino-cyanide of barium, such as is used for X-ray work, shows the effect in a marked degree. In other cases it is necessary to wait in a dark room for ten or fifteen minutes before the eye becomes sufficiently sensitive to detect the fluorescence. It is probable that the eye itself fluoresces to some extent, as a curious sensation of light is experienced when the radium (in a sealed case) is brought near to it. A sufficiently pure sample of radium is visible in the dark, but it is probable that this luminosity is a secondary effect, a fluorescence excited by the radium rays.

(The fluorescence of a screen coated with barium platino-cyanide was shown. When a sample of radium was introduced into the mouth of a bottle containing platino-cyanide of potassium the whole bottle appeared luminous in the dark).

Sir William Crookes has discovered that a screen of crystalline sulphide of zinc, when a radium salt is brought near to it, shows on examination by a pocket lens a number of bright scintillating spots. "On bringing the radium nearer the screen, the scintillations become more numerous and brighter, until when close together the flashes follow each other so quickly that the surface looks like a turbulent luminous sea." (*Nature*, 67, p. 522, 1903). The scintillations are also shown by platino-cyanide of barium and the diamond. Sir William Crookes has given the name "spinthariscope" to a small instrument designed for the study of this phenomenon. The scintillations are stopped by placing a piece of card between the radium and the screen.

It is probable that the scintillations are produced by a bombardment of the screen by material particles shot off from the radium with a velocity approaching that of light. Becquerel believes that they are due to minute fractures taking place in the crystals under the impact of the α rays.

3. Special interest attaches to the effect of the rays from a radio-active body on a photographic plate as it was by this means that Becquerel first discovered the radio-activity of uranium.

An observation which I made about a month ago makes it possible that the photographic effect ought to be classed under the previous head as due to fluorescence. Having been for some time in the dark room I brought the radium in its case close to an unexposed plate, and found that there was a decided fluorescence of the plate. A large part of the effect is due to the glass, for a piece of plain glass also shows fluorescence, but a certain proportion is due to the sensitive film, for a plate which has been developed and fixed does not fluoresce as brightly as an unexposed plate. A flexible film (Carbutt's) also fluoresces under the influence of the radium rays, and so does a piece of ordinary bromide paper, though in the latter case the effect is very feeble.

I thought that it would be interesting to see whether X-rays would produce a similar fluorescence, and so I examined a photographic plate under the action of these rays, taking care to shield the eyes and the plate itself from the ordinary light from the focus tube. The plate became markedly fluorescent after the rays had passed through two sheets of thick black paper, or one thickness of tinfoil. It was quite possible to distinguish the shadow of the finger on the illuminated plate. The luminosity produced when the radium was brought close to the plate was greater than that caused by the X-rays.

I cannot say whether these results are entirely new as I have not been able to make a detailed examination of the literature of the subject.[1]

(Lantern-slides were exhibited showing the power of the radium rays of acting on a photographic plate, so as to give an image capable of development).

4. Among the most remarkable properties of radium is the fact discovered by Curie and Laborde (C.R., March 16th, 1903) that its salts give off heat continuously. During every hour of its existence one gram of radium is emitting 100 calories, that is to say, it is capable of melting 1.25 grams of ice every hour. It is interesting to compare the rate at which radium supplies energy with the activity of more familiar agencies. One horse power is equivalent to 746 watts; expressed in heat units this is the same

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[1] Note added Dec. 15th.—In his original communication announcing the discovery of the X-rays, Röntgen says:—"It appears questionable, however, whether the chemical action on the silver salts of the photographic plates is directly caused by the X-rays. It is possible that this action proceeds from the fluorescent light which is produced in the glass plate itself, or perhaps in the layer of gelatin. 'Films' can be used just as well as glass plates." (Harper's Scientific Memoirs, Röntgen Rays, p. 6.)

as 178 calories per second, or about 640,000 calories per hour. Thus for a continual supply of energy at the rate of one horse power we should require 6.4 kilograms (say about 13lbs.) of radium. Compare with this the fact that a petrol motor used to drive a motor bicycle may weigh 15lbs. per horse power. It should of course be understood that figures such as these are purely illustrative, as the temperature differences involved in the case of radium are so small as to render only a small part of the heat energy available for useful work.

The fact that a radium salt yields a continuous supply of electrified particles and light waves is itself a proof of the production of energy, so that even apart from the remarkable result as to the emission of energy in the form of heat we are brought face to face with the question—what is the source of this energy? It is true that the study of radium seems likely to revolutionise many of our scientific ideas, but we are not willing to abandon the principle of the conservation of energy without a struggle.

According to the view developed by Professor Rutherford and the Canadian physicists, the energy of radium is derived from the deflagration of a minute portion of the explosive radium atoms. In ordinary cases of chemical combination we have to deal with the energy of molecules as dependent on the arrangement of the atoms within them, here it is the internal energy of the atom itself that is in question.

5. In January, 1900, Rutherford (*Phil. Mag.*, vol. 49 (5), p. 1) showed that thorium in addition to producing "rays" of the classes already referred to, continuously emits a gaseous substance which is itself radio-active. This property of radio-activity possessed by the gas serves to distinguish it from the feebly penetrating (α) rays of thorium. To this substance Rutherford gave the name "emanation." The emanation behaves like an ordinary gas, in that it can pass through a plug of cotton-wool or bubble through water without losing its radio-active powers. An ion, on the other hand, would lose its charge under such treatment.

Radium also gives rise to an emanation, but, while the thorium emanation remains active for only a few minutes, that from radium retains its activity for some weeks. We have collected a sample of the emanation from radium, by allowing it to diffuse into a glass bulb with a constricted neck, and then sealing off the bulb with the blowpipe. This bulb then behaves as a source of radio-activity, and although the quantity of emanation in it is too small to be weighed or measured, its presence can be detected with the greatest ease by means of an electrometer.

As though the emanation itself were not sufficiently remarkable there is yet another step in the production of radio-active matter. If the emanation is blown out of a vessel containing it, there remains attached to the walls of the vessel a something (not emanation) that is also radio-active. This "something" has been termed "excited" or "imparted" activity.

Rutherford and Soddy (*Phil. Mag.*, vol. 5, p. 576, 1903) attribute these new radio-active substances to the disintegration of the radium atoms. At any instant a certain proportion of the atoms in a sample of radium are unstable and literally break in pieces shooting out heavy charged particles, and leaving the "emanation" as the residue. This in turn breaks down leaving the "excited activity" and there is strong evidence to show that the final stage is reached in the production of the inert gas helium.[1] (Ramsay and Soddy, *Proc. Roy. Soc.*, vol. 72, p. 204, 1903).

6. The physiological effects of radium rays are also of great interest. Becquerel has recorded the fact that a few milligrams of radium in a glass tube carried in his waistcoat pocket produced a sore, lasting for several weeks. Dr. John Macintyre has described in the British Medical Journal (June 6th, 1903) a similar experiment of which he was himself the subject. Several investigations are now being carried on with regard to the therapeutic action of the rays, but such enquiries must necessarily extend over a considerable time before reliable results can be secured.

Professor Curie is reported to have said that "he would not care to trust himself in a room with a kilogram of pure radium, because it would doubtless destroy his eyesight, burn all the skin off his body, and probably kill him."

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[1] In connection with the theory of the transmutation of the radio-active elements into simpler bodies I venture to offer a suggestion of a somewhat speculative character to physiological chemists. Radium, thorium, uranium are the three heaviest elements known, and they are radio-active, the radio-activity being attributed to the instability of their atoms. The most complicated molecules with which we are acquainted, are those organic compounds that occur in living organisms. Can we draw any analogy between "radio-activity" on the one hand and "vitality" on the other?

PART II.

In the first part of the paper I have given some account of the history and properties of radium, and now I propose to deal with some special questions relating to radio-activity, which have been the subject of research at the Blythswood Laboratory.

INFLUENCE OF RADIUM-RADIATION ON SPARK LENGTH.

In consequence of the ionisation produced in air by radium rays it is easier for a spark to cross a spark-gap when radium is near. I have measured the potential difference across a spark-gap about 1 mm. wide by means of a Kelvin electrostatic voltmeter, and then noted the fall in potential due to the presence of radium. With a sample of radium (about 5 milligrams) in a lead box with an aluminium cover placed at a distance of 8 cm. from the gap the electrometer reading fell from 38 to 22.

> (The effect of radium rays on a spark-gap was shown experimentally with the induction coil).

A simple way of showing that radium radiation increases the conductivity of the air is to arrange two spark-gaps in parallel, one being subject to the action of the radium, the other being shielded from its influence. Then, if the length of the gaps is adjusted so that sparking occurs at both simultaneously, it will be found that the gap influenced by the radium is the greater of the two. Such an arrangement I set up in connection with the large Wimshurst machine, each spark-gap being provided with a micrometer-screw adjustment so that its length could be accurately measured. The length of the ordinary spark was altered by half a millimetre at a time, and the gap subject to the radium was adjusted till sparking took place at both gaps. The exact point could not be determined very definitely as sparks would cross both gaps though the " radium gap " were slightly increased or diminished.

Mr. John Purdie of Glasgow University made a series of measurements of spark-lengths for me by this method. The first set of experiments was made with spherical terminals. With gaps about 1 mm. long there was not much difference in length, but as the gap increased so did the difference between the two gaps, until for a 3 mm. gap the difference amounted to 15 per cent. After this, the difference again diminished. When point terminals were used the difference between the gaps was more marked. The radium produces more apparent effect in this case. As with the spherical terminals the difference was most pronounced for a gap 3 or 4 mm. long, but in this case the spark-gap subject to the radium rays was three or four times as long as the ordinary gap.

RADIUM RADIATION AND CONTACT ELECTRICITY.

In a paper by Lord Blythswood and myself which has been communicated to the *Philosophical Magazine* by Lord Kelvin an account is given of some experiments which we have carried out on the volta effect in air under the influence of radium radiation. When two insulated plates of different metals are placed in air thus ionised, similar wires connected with the plates acquire a difference of potential. This potential difference may be measured by a sensitive electrometer. It is of the same order of magnitude as that which would be obtained by connecting the metal plates with a drop of water. This effect was first observed in air under the radio-active influence of a disk of the metal uranium by Lord Kelvin, J. C. Beattie, and M. S. de Smolan (*Phil. Mag.*, vol. 45, p. 277, 1898).

Our measurements show that when radium is employed as the source of radiation (β and γ rays) the metals zinc, aluminium, lead, tin, bismuth, antimony, iron, copper, silver, gold, platinum, fall into their places in the voltaic series.

Experiments carried out with a tube that could be exhausted to 1/7000 mm. of mercury showed that the potential-difference between platinum and aluminium did not alter by so much as 5 per cent. as the pressure was varied from that of the atmosphere to the lowest pressure attainable.

RADIO-ACTIVE GAS IN BATH MINERAL WATERS.

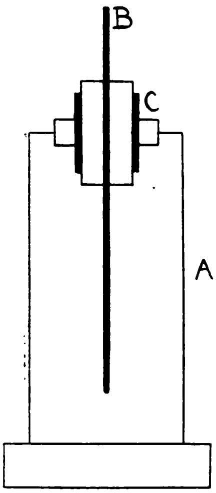
Professor J. J. Thomson has shown that the air extracted from Cambridge tap-water and from the water of certain deep-level springs is mixed with a radio-active gas. (*Nature*, vol. 68, p. 90, 1903.) This gas has been further examined by Mr E. P. Adams, (*Phil. Mag.*, vol. 6, p. 563, 1903), who comes to the conclusion that the water radio-activity is due to a substance very similar to, if not identical with, the emanation of radium.

It appeared to Lord Blythswood and myself that it would be of special interest to determine whether any such constituent is present in the waters from the hot mineral springs of Bath. As is well known these waters come from a great depth, issuing at a temperature varying from 116° to 120° Fahrenheit. Samples of water taken from the King's Bath Spring were sent to the laboratory at Blythswood in carefully sealed vessels, and experiments were there made to see whether any radio-active gas were present in solution. In the first experiments the gas was expelled from a flask containing a litre and a half of water by boiling under a pressure of about half an atmosphere. After passing through a number of drying tubes, the gas was collected in a cylindrical "vacuum tube" provided with aluminium electrodes. The amount of gas so obtained was small as was shown by the fact that the pressure only altered by a few centimetres of mercury. In order to test the gas for radio-activity the rate of leak from one electrode to the other was measured by a quadrant electrometer. On the first trial it was found that there was no alteration in the rate of leak immediately after the introduction of the gas from the Bath water, and it was somewhat hastily concluded that the gas was not radio-active. Happening, however, to take a reading of the electrometer about an hour after the gas had been collected, I found that the rate of leak had increased. This led to my taking a series of readings with a fresh supply of gas after successive intervals of five minutes. It was then found that after the introduction of the gas into the testing vessel, the rate of leak gradually increased to a maximum value, which was reached in about an hour, and then again diminished.

Experiments were then commenced on a slightly different plan. Instead of expelling the gas by boiling the water, it was extracted by exhausting the testing vessel, and allowing a current of air to bubble through the water, and a series of drying-tubes into the vessel. In this way the testing vessel was filled with dry air mixed with Bath gas. A new testing vessel was constructed on the plan shown in the figure.

A is a brass cylinder of about 350 c c. capacity. B is a brass rod in the axis of the cylinder serving as one electrode, the cylinder itself being the other. The brass rod passes through an ebonite plug fitted into a short length of brass tubing C. This brass tube fits into an ebonite disk in the cover of the cylinder. The joints were made air-tight by means of sealing-wax

The cylinder, which is insulated by being placed upon a block of paraffin, is connected to one pole of a battery of storage cells, the other pole being to earth. The brass tube C is also put to earth. In this way no charge can leak from the jar to the brass wire across the insulation, any leak that takes place must be through the air in the cylinder. Defective insulation can only result in a decrease in the effect to be observed. In the first experiments a battery of 56 volts was employed, but recently a battery of 200 small lead cells has been set up so that any desired voltage up to 400 volts may be used. With this apparatus experiments were made confirming the results obtained by the former method. The rate of leak increased to a maximum in about an hour after the introduction of the gas. About half an hour later the activity had diminished to one half the maximum value, and two hours after the commencement of the experiment, the additional leak had become too small to be observed. The effect to be measured is extremely small, and at present it is difficult to give exact quantitative results, but we hope soon to be able to make some tests with more sensitive apparatus.



The question then arises what interpretation can be given of these results? According to the experiments of Rutherford and Soddy (*Phil. Mag.*, vol. 5, p. 447, 1903) when the emanation from radium mixed with air is introduced into a closed space the ionization-current increases, rapidly at first, and then more gradually until it attains a maximum after 5 or 6 hours, and then it decreases according to an exponential law. This increase they explain as being due to the production of "excited" activity from the emanation. A maximum is reached when the decay of excited activity just balances the continuous production of fresh active matter. Thus it appears that the gas extracted from the Bath water and introduced into the testing vessel behaves in a manner similar to the emanation from radium, though there appears to be a difference in the time constants involved. Whether this difference is due to the conditions of the experiments is not yet clear, so that at present it is uncertain whether the radio-active gas from Bath water is identical with the emanation of radium, or whether it corresponds to some other (possibly unknown) radio-active element.[1]

With Lord Blythswood I have also made tests of the water from the sulphur springs at Harrogate, but in this case no trace of radio-activity has so far been detected. This is scarcely surprising in view of the fact that these are not deep-level waters.

Within the last fortnight we have tested samples of water from Buxton. The waters rise through fissures in the mountain limestone at a temperature of 82° Fahrenheit. The results obtained by bubbling air through the water were exactly similar in character to those given by Bath waters. There was the same gradual rise in the ionization-current for the first hour followed by a fall to the normal value.

In the King's Bath Spring at Bath it is said that "gases gurgle through the water," while at Buxton large bubbles of gas are described as rising through the waters " in frequent but intermittent bursts." The atmosphere in the immediate neighbourhood must therefore contain a certain proportion of radio-active gas.

It is possible that the therapeutic action of the Bath and Buxton waters may be due in some degree to the radio-activity of the gases contained in them, but to prevent misconception it should be said that at present there is no proof of this being the case. If it be so, then the fact that the activity of the gas now being investigated begins to decrease so soon after the gas has been liberated, acquires special significance. For in this fact we may possibly find an explanation of the belief that the waters of certain spas possess greater efficacy when used on the spot.

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[1] Note added Dec. 15th.—Since the paper was written we have carried out an experiment following the method employed by Mr. Adams (*loc. cit.*). A very dilute solution of a radium salt was prepared in a flask, whose capacity was about one litre. A current of air was drawn through the solution, and then through a Winchester quart containing distilled water, a plug of glass wool being then interposed between the two vessels to prevent any spray from the radium solution being carried over with the air. The air current was continued for two hours. The distilled water after this treatment was tested in exactly the same manner as the Bath water. The rate of leak increased to a maximum in about one hour from the commencement of the experiment, the results being in all respects similar to those obtained from the mineral waters. It is therefore probable that the radio-activity of these waters is due to the presence of radium near their source.

It should be noted that in all our later experiments the testing vessel was permanently connected to the negative pole of the battery.

The discovery of a radio-active gas in the waters from the Bath springs is also interesting, as it is known that those waters contain gases of the argon group. In 1895, shortly after the discovery of helium by Professor Ramsay, Lord Rayleigh (British Association, 1895, *Proc. Roy. Soc.*, vol. 59, p. 206, 1896), showed that helium was present among the gases from the Bath springs.[1] Gas from the Buxton springs gave a doubtful indication of helium.

I cannot conclude this paper without expressing my indebtedness to Lord Blythswood for his continued kindness, and in particular for having given me every facility for showing the experiments which I have been able to bring before you this evening.

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[1] I take this opportunity of apologising for having, in a letter to *Nature*, of August 13, 1903, overlooked the fact that Lord Rayleigh was the first to prove the presence of helium in the Bath gas.

CENTENARY LECTURES, NO. II.

Some Developments in Chemical Theory during the Nineteenth Century. By G. G. HENDERSON, M.A., D.SC., F.I.C., Professor of Chemistry in The Glasgow and West of Scotland Technical College.

[Prepared by the request of the Council and read before the Society, 13th January, 1904.]

THE flowing tide of discovery in chemical science did not set in until the beginning of the nineteenth century, because, although much work had been done and much information acquired previously to this period, it was in the opening years of the century that the system of chemical theory, by which experimental investigation is inspired and directed, had its origin. It was in 1803 that the Atomic Theory, the foundation upon which the edifice of modern chemistry has been erected, was set forth by John Dalton. Dalton was the first to point out that when the simple stuffs called elements enter into chemical union with each other so as to produce the more complex stuffs called compounds, the process of combination takes place according to definite laws, which may be stated as follows:—(1) When two or more elements combine to form a compound, they combine in constant proportions by weight. (2) When two or more elements combine to form more than one compound, they combine in simple multiple proportions. For example, one part of the element hydrogen combines with eight parts of the element oxygen to form nine parts of the compound water, and water, no matter how prepared, is always composed of those elements united in this proportion. Again, as an illustration of the second law, the elements nitrogen and oxygen unite in different proportions to form five different compounds, in which fourteen parts of nitrogen are combined with eight, sixteen, twenty-four, thirty-two, and forty parts respectively of oxygen. In order to afford an explanation of these facts Dalton revived the ancient speculation of the Greek philosophers that all substances are made up of atoms, but at the same time gave to it a precise and definite form. According to his view the atom is a particle which cannot be divided. Each element is composed of homogeneous atoms, of which the weight is constant, but the atoms of one element differ in weight from those of another element. Chemical compounds are formed by the union of the atoms of their constituent elements in simple numerical proportions. If the atoms are conceived as minute spheres, capable of aggregating themselves together under suitable conditions to form complexes, or molecules, a mental picture of chemical substances can be formed. Thus a chemical representation can be given of the compound water, the molecule of which is composed of two atoms of hydrogen and one atom of oxygen, by bringing two spheres of the same kind, representing hydrogen atoms, in conjunction with a sphere of a different kind representing an atom of oxygen. Atoms are almost inconceivably small. It has been calculated that the diameter of a molecule of hydrogen is 0·11—0·14 micro-millimetre (the micro-millimetre is one millionth of a millimetre), and as each molecule of hydrogen is composed of two atoms, some idea of the size of an atom can be formed in this way. It is obvious, therefore, that there is no available method of ascertaining the absolute weights of the atoms. On the other hand, their relative weights can be determined with great exactitude, and Dalton indeed proceeded to determine the atomic weights of a number of the elements. Starting with the assumption that the atoms are always united in the simplest possible manner, he proceeded on the principle that when two elements unite to form only one compound, the molecule of the compound is composed of one atom of each element; that when two elements unite to form two compounds, the molecule of one compound is composed of one atom of each element, whilst the molecule of the other compound consists of one atom of the one element united with two atoms of the other; and so forth. He then ascertained the proportions by weight in which the elements are united in their compounds, and applying the principle just mentioned, arrived at the atomic weights of the elements. As unit he took hydrogen, the lightest of the elements, with the atomic weight = 1. For example, in the compound water one part of hydrogen is united with eight parts of oxygen; if the molecule of water is composed of one atom of hydrogen and one atom of oxygen, the atom of oxygen is eight times heavier than the atom of hydrogen, or in other words the atomic weight of oxygen is 8. But a difficulty at once presents itself, for in order to determine atomic weights it is necessary to know the number of atoms in the molecules of the compounds examined. How, for example, can the number of atoms of hydrogen and of oxygen in a molecule of water be determined, or, in the case of elements combining to form more than one compound, how can it be discovered which of these compounds contains only one atom of one of the elements composing its molecule? Although aware of this difficulty Dalton could see no way to escape from it, and contented himself by assuming that the atomic weights were those weights of the elements which gave the simplest proportions between the numbers of the constituent atoms in all known compounds of the elements. Moreover, he did not possess the necessary analytical skill for the accurate determination of the composition of compounds. This work was taken up by Berzelius, who prepared and analysed with truly marvellous ability an amazing number of new compounds. Berzelius also, like Dalton, had no data to guide him in his choice of the atomic weights, although by intuition he arrived at the right number in many cases, for even by comparing the composition of all the compounds which one element forms with others it is impossible to ascertain which of these compounds contains only one atom of the element in its molecule. Dalton and Berzelius, as a matter of fact, could not do more than determine the *equivalents* of the elements, that is, the weights of the elements which combine with or replace one part by weight of hydrogen.

The solution of the problem was arrived at chiefly through the experimental work of Gay-Lussac, who studied the proportions by volume in which gases combine with each other and stated the results of his experiments in the following generalisation. Two gases always combine in simple proportions by volume, and the volume of the (gaseous) product stands in the simplest relation to the volumes of the constituents. Thus, one volume of hydrogen and one volume of chlorine give, when combined, two volumes of hydrochloric acid; two volumes of hydrogen and one volume of oxygen give two volumes of water vapour; similar simple relations are observed in the case of other gases. Gay-Lussac pointed out that his facts were in accord with the atomic theory, and, moreover, that the analogous behaviour of gases towards changes of pressure and temperature could be explained if a similar atomic condition in all gases were assumed. There was, however, a real difficulty in bringing Gay-Lussac's law into harmony with the atomic theory, for this involved the assumption that equal volumes of gases contain equal numbers of atoms, and Dalton brought forward experimental evidence to prove that this is impossible.

The way of getting over this difficulty was indicated by Avogadro. Dalton supposed that atoms of elements united to form atoms of compounds, but Avogadro explained that a distinction must be drawn between the atom and the *molecule*, the smallest conceivable particle of a substance which can exist in the free state. The molecules are not the ultimate particles of substances, but are capable, under the action of chemical forces, of sub-division into atoms. Thus the molecule of the compound water is composed of three atoms, two of hydrogen and one of oxygen, but the particles of gaseous hydrogen or oxygen are also molecules, each composed of two atoms. From this point of view the combination of elements is to be regarded not simply as a case of combination of atoms, but rather as an exchange of atoms between re-acting molecules. If the symbols H and Cl are used to represent one atom of each of the elements hydrogen and chlorine, Dalton's idea of the formation of hydrochloric acid would be represented thus, $H + Cl = HCl$, whilst according to Avogadro's view the expression of the reaction would be $H{\cdot}H + Cl{\cdot}Cl = H{\cdot}Cl + H{\cdot}Cl$. Taking into consideration the physical properties of gases, and in particular the similarity in their behaviour when exposed to similar changes of temperature and pressure, Avogadro was led to the assumption that equal volumes of all gases, under similar conditions of temperature and pressure, contain equal numbers of molecules. If this be granted, it follows that the proportion between the weights of the molecules is the same as the proportion between the weights of equal volumes, or the relative densities, of the gases. Here, therefore, is an experimental method for determining the relative weights of the molecules of all substances which can be converted into the gaseous state without undergoing decomposition. The weight of the molecule of hydrogen, which is less than the weight of the molecule of any other known element, is chosen as the standard for comparison, so that the term "molecular weight" is understood to mean the weight of the molecule of any substance as compared with the weight of a molecule of hydrogen. Now if a large number of compounds of any one element be taken, it is probable that one at least of these contains only one atom of the element in its molecule; hence, when the composition and the molecular weight of each of the compounds are known, the smallest weight of the element which enters into the molecule of any of its compounds is taken as the atomic weight. Strictly speaking, this method gives the maximum value of the atomic weight.

As it is of the first importance that the relative weights of the elementary atoms should be ascertained with the greatest possible accuracy, any means of checking the results obtained by the application of Avogadro's hypothesis is of value. One method is due to the discovery by Dulong and Petit that the atoms of the solid elements have the same capacity for heat, or, in other words, that if quantities of the different elements be taken proportional to their atomic weights, equal quantities of heat must be imparted to them in order to raise their temperature to the same extent. Dulong and Petit's law may be stated thus :—The specific heats of the elements are (approximately) inversely proportional to their atomic weights, or the atomic heats of the elements, *i.e.*, the products of the specific heats into the atomic weights, are (approximately) equal. The value of the atomic heat is approximately a constant, not differing much from the number six, and therefore the quotient of six by the specific heat should be (approximately) equal to the atomic weight of an element. Since the specific heats of the elements can be ascertained by experiment, the application of Dulong and Petit's law provides another direct method of determining atomic weights, although, of course, the results are only approximate.

A third method of arriving at the correct atomic weights of the elements was suggested by Mitscherlich. Different substances sometimes crystallise in the same form, and are then said to be isomorphous with each other. Isomorphous substances are often chemically similar to each other in the sense that their molecules contain the same number of atoms. According to Mitscherlich when one element replaces another in an isomorphous crystal of the same chemical character, the substitution occurs in such a way that one atom of the one element replaces one atom of the other. Hence, if the atomic weight of the one element be known, that quantity of the other which replaces a quantity of the first proportional to its atomic weight, must also be proportional to the atomic weight of the other element. For example, the carbonates of calcium and barium are isomorphous; corresponding quantities of the two compounds contain forty parts of calcium and one hundred and thirty-seven parts of barium; the atomic weight of calcium is forty, and therefore the atomic weight of barium must be one hundred and thirty-seven. However, caution is necessary in the application of the results obtained by the examination of isomorphous substances, for there are many exceptions to Mitscherlich's rule.

Before passing from the subject of atomic weights it must be noted that if the values of the atomic weights of the elements are compared with the values of their molecular weights, assuming Avogadro's rule to hold good in all cases, most interesting results are obtained. The conclusion necessarily arrived at is that the molecules of certain elements, notably those of the helium group, are composed of only one atom, that the molecules of many others, for example hydrogen, oxygen, and chlorine, are diatomic, and finally, that in some cases the molecules of elements are composed of four, or even more than four atoms. In this way a conception of the molecular structure of the elements can be formed.

Observation of the composition of compounds brings to light the fact that the atoms of different elements combine together in different numerical proportions; for example, one atom of chlorine combines with one, and not more than one, atom of hydrogen, one atom of oxygen with two atoms of hydrogen, one atom of nitrogen with three atoms of hydrogen, one atom of carbon with four atoms of hydrogen, and so on. The atomic theory in its original form gave no explanation of this property of the atoms, and it was not until nearly fifty years had elapsed since the first publication of this theory that the deficiency was remedied by Frankland's enunciation of the doctrine of valency. According to this doctrine the atoms of certain elements, for example, hydrogen and chlorine, are incapable of uniting with more than one atom of another element; these elements are termed monovalent. Other atoms, such as those of calcium and zinc, can become directly attached to at most two other atoms; these elements are divalent. Tri-, tetra-, penta-, hexa-, hepta-, and octavalent elements can be similarly distinguished. In order to measure and define this capacity for saturation, or atom-fixing power, of the atoms of other elements the valency of hydrogen is taken as unity. If the atoms are represented by spheres provided with as many pegs as the atoms possess units of valency, compound molecules can then be represented in a roughly diagrammatic way by fitting the atoms together by means of the pegs representing the number of units of valency possessed by the different atoms composing the molecule in such a manner that each peg is joined to another peg. A mental picture can thus be obtained of the way in which the atoms are linked together within the molecule itself. The acceptance of this doctrine of the valency of the atoms marks a great advance upon the atomic theory of Dalton's time.

The relation between the atomic weights of the different elements has been for long a subject of speculation. Early in the nineteenth century Prout suggested that, since it was possible that the ancient dictum of the uniformity of matter was true, the primary material might be hydrogen, and the atomic weights of the other elements should, therefore, be simple multiples of that of hydrogen. Berzelius, relying on his own determinations of atomic weights, took a prominent part in opposing the suggestion, and although Prout's idea was subsequently revived in a modified form, it has ultimately been disposed of by the very exact determinations of atomic weights which have been made by many chemists, among whom Stas occupies a prominent place. Omitting any reference to other attempts to correlate the properties of the elements with the relative weights of their atoms it must be noted that a great advance was made when Newlands drew attention to the remarkable fact that, if the elements are arranged in the order of their atomic weights, every eighth element, starting from a given one, is a kind of repetition of the first, like the eighth note of an octave in music. This "law of octaves" did not receive at the time the attention which it deserved, and it was not until a number of years had passed that it was rediscovered independently by Mendeléeff and Lothar Meyer. They both pointed out that if the elements are arranged in the order of their atomic weights, a variation in the properties of the elements is observed in passing from member to member of the series, but that elements which are similar in character occur in the series at approximately equal intervals. In the light of known facts they came to the conclusion that the chemical and physical properties of the elements are periodic functions of their atomic weights. This generalisation, which is termed the Periodic Law, has been adopted as the basis of chemical classification. If the elements are arranged in the order of their atomic weights, but if, instead of all of them being placed in a horizontal series, those which are

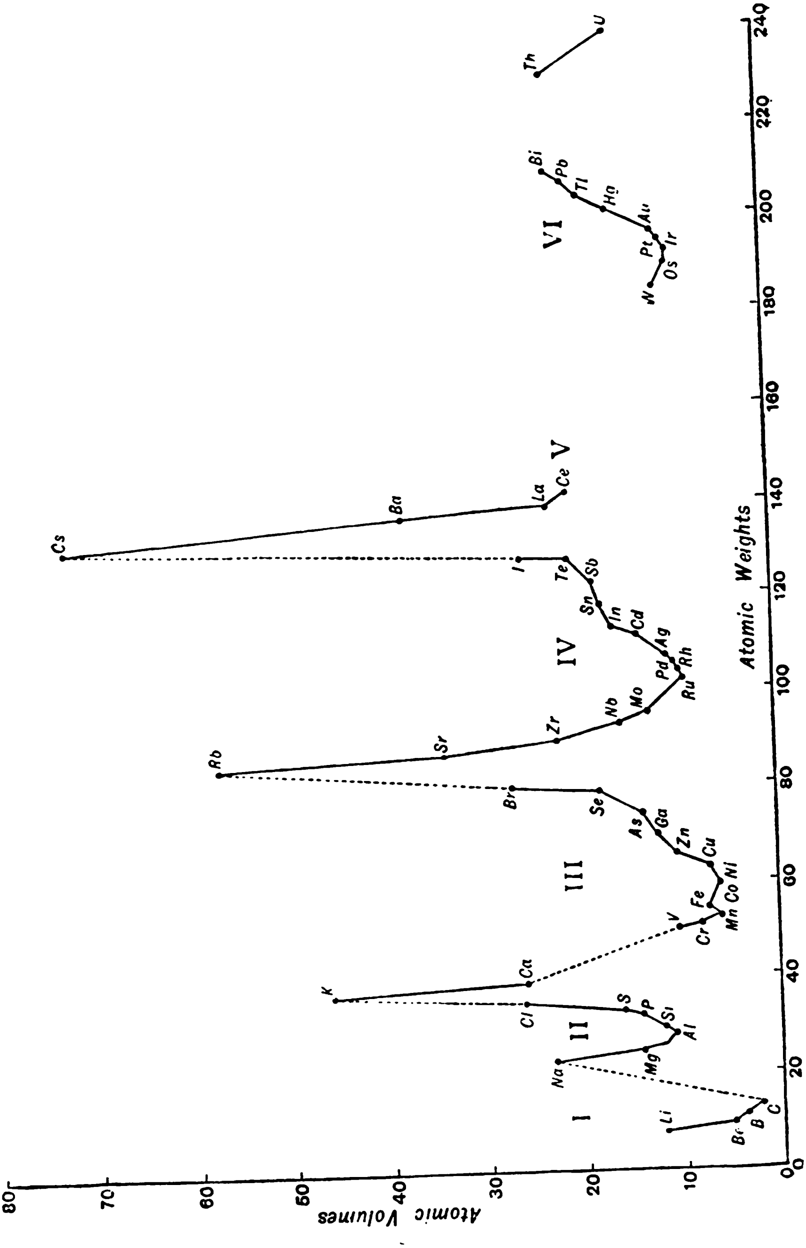
THE ATOMIC WEIGHTS OF THE ELEMENTS ARRANGED ACCORDING TO THE PERIODIC SYSTEM.

							H 1			
He 4	Li 7	Be 9	B 11	C 12	N 14	O 16	F 19			
Ne 20	Na 23	Mg 24	Al 27	Si 28·5	P 31	S 32	Cl 35·5			
A 40	K 39	Ca 40	Sc 44	Ti 48	V 51	Cr 52	Mn 55	Fe 56	Co 59	Ni 58·7
	Cu 63·5	Zn 65·5	Ga 70	Ge 72·5	As 75	Se 79	Br 80			
Kr 82	Rb 85·5	Sr 87·5	Y 89	Zr 90·5	Nb 94	Mo 96	—	Ru 101·5	Rh 103	Pd 106·5
	Ag 108	Cd 112·5	In 114	Sn 119	Sb 120	Te 127·5	I 127			
X 128	Cs 133	Ba 137·5	La 139	Ce 140	Pr 140.5	Nd 143·5	Sm 150	—	—	—
	—	—	—	Er 166	—	—	—			
—	—	—	Yb 173	—	Ta 183	W 184		Os 191	Ir 193	Pt 195
	Au 197	Hg 200	Tl 204	Pb 207	Bi 208·5	—	—			
—	—	Ra 225	—	Th 232·5	—	U 238·5	—	—	—	—

similar in properties are arranged in vertical columns, nine groups are arrived at, as shown in the foregoing table. The elements in those groups are on the whole those which would naturally fall together in a classification of the elements according to their general chemical character.

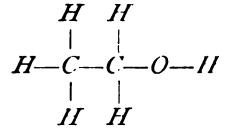
The periodicity in the properties of the elements can be illustrated graphically by taking as an example the atomic volumes of the elements. (The atomic volume is the quotient of the atomic weight by the specific gravity). If the atomic weights are tabulated on the horizontal axis, and the atomic volumes on the vertical axis, the points thus obtained lie in a series of curves which resemble each other closely in general appearance. If the whole series be regarded as a single curve, that curve is a periodic one, *i.e.*, a curve which repeats itself after a certain interval; each repetition is called a period. An inspection of the curve of atomic volumes show that elements which occupy similar positions in the curve are similar in chemical character. When the numerical values of most of the well-defined properties of the elements, for example, specific gravity, melting point, and magnetic power, are similarly tabulated against the atomic weights, the curve obtained is a periodic curve in each case.

As regards the blank spaces in the table of atomic weights, it is only reasonable to expect that some, if not all of them, will be filled up by elements as yet undiscovered. When the table was first constructed the number of blank spaces was greater than now, and Mendeléeff ventured to predict not only the existence of elements to occupy some of the gaps, but even their chief properties, taking into consideration the properties of the elements nearest to them in the table. His predictions were fulfilled in the case of the elements gallium, germanium, and scandium, which were isolated subsequently, and radium, the most recent addition to the list, also appears to fall naturally into one of the spaces on the table. But the Periodic Law may be applied not only to foretelling the character of elements still unknown, but also to checking the determinations of the atomic weights of the elements. For example, the element beryllium was formerly regarded by many chemists as a metal related to aluminium, and of atomic weight 13.5. Mendeléeff pointed out, however, that there was no place in the periodic table for an element of this atomic weight, and he therefore assigned to beryllium the atomic weight 9, placing it in the group along with magnesium. This step was


Atomic Volumes
0
10
20
30
40
50
60
70
80
Atomic Weights
0
20
40
60
80
100
120
140
160
180
200
220
240
I
II
III
IV
V
VI
Li
Be
B
C
Na
Mg
Al
Si
P
S
Cl
K
Ca
V
Cr
Mn
Fe
Co
Ni
Cu
Zn
Ga
As
Se
Br
Rb
Sr
Zr
Nb
Mo
Ru
Rh
Pd
Ag
Cd
In
Sn
Sb
Te
I
Cs
Ba
La
Ce
W
Os
Ir
Pt
Au
Hg
Tl
Pb
Bi
Th
U

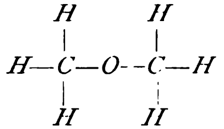
fully justified by more recent determinations of the atomic weight of beryllium.

Another important stage in the development of chemical theory was reached when the idea was introduced that the chemical individuality of a substance is dependent, not only upon the *composition*, but also upon the *constitution* of the molecule. The necessity for the recognition of this fact arise principally from the extension of our knowledge of the so-called organic compounds, *i.e.*, the compounds of carbon. For some time after the beginning of the period under review it was believed that those substances which nature produces exclusively in living organisms constituted a group sharply differentiated from those inorganic substances which occur in the mineral kingdom, or which can be prepared in the laboratory. According to Berzelius, a special "vital force" was necessary for the production of organic compounds, and therefore the building up of these compounds from their elements could not be effected except in a living plant or animal. However the belief in this "vital force" was long ago set aside by experiment. In 1828 Wöhler for the first time succeeded in preparing a typical organic compound, urea, from mineral substances, and since then similar results have been obtained in great number. It is true that some naturally occurring products have not yet been prepared in the laboratory, but there is no reason for doubting that what has happened in so many cases will happen in all. On the other hand there is every reason for believing that organic and inorganic substances are subject to the same laws, and that the elementary atoms are brought into combination to form organic molecules by the same forces as bring about the formation of inorganic molecules. In the early part of the nineteenth century it became evident, chiefly from the work of Liebig, Wöhler, and Faraday, that compounds of carbon exist which possess entirely different properties, but yet have the same molecular composition. Such substances are called isomeric. As time passed the number of such cases increased, and the existence of this phenomenon of isomerism became fully realised; hence the atomic theory was naturally called upon to furnish an adequate explanation. Since it was proved that the composition of the molecules of such isomeric substances was the same, or in other words that the molecules of these compounds were composed of the same numbers of atoms of the same kind, it was clear that the explanation must be sought for in a difference of the arrangement of the elementary atoms within the molecule. Therefore the investigation of the *constitution* of organic compounds, that is, the mode in which the elementary atoms are linked together within the molecule, the functions of the several atoms, and the relation of each atom to the other atoms composing the molecule, became of the first importance. Time does not permit of more than the mention of earlier theories regarding the constitution of compounds, such as the electro-chemical theories of Davy and Berzelius; the theory of radicles, based chiefly upon the classical researches of Gay-Lussac, Liebig, Wöhler, and Bunsen, and set forth by Berzelius, Liebig, and Dumas; and the theory of types, founded mainly upon the experimental work of Hofmann, Williamson, and Würtz, first stated by Dumas, and fully developed by Gerhardt. None of these theories, although each was of the greatest service in promoting investigation, proved adequate to explain all the known cases of isomerism. In order to arrive at an understanding of the constitution of the molecule, it was necessary to go back to the ultimate constituents, the elementary atoms, and thus there arose the structural theory, or theory of atomic linkage. This theory owes its origin to Graham, Williamson, Odling, Couper, and Kekulé, its development mainly to Kekulé. It is based upon the fundamental conception of the valency of the atoms, which, as already stated, was first clearly explained by Frankland, and according to which every elementary atom is incapable of combining with more than a limited number of other atoms. For every atom this "valency" is a characteristic property; thus the valency of hydrogen is one, of oxygen two, of carbon four, or in other words the atoms of those elements have one, two, or four units of valency respectively. According to the structural theory molecules are so composed that each unit of valency of each atom present in the molecule is combined with a unit of valency of another of the constituent atoms of the molecule. Accepting this conception it is easy to understand how cases of isomerism can arise, for it is obvious that, given a certain number of atoms of different kinds, these can be linked together in different ways, but always so that all the units of valency of each atom present in the molecule are combined with the units of valency of the other constituent atoms. To take an example, ethyl alcohol and methyl ether differ greatly from each other both in physical and chemical properties, but possess the same molecular composition, the molecule in each case consisting of two atoms of carbon, six of hydrogen, and one of oxygen. The composition of each molecule is represented by the formula C_2H_6O. The difference in constitution can be represented by the following constitutional formulæ, remembering that hydrogen is monovalent, oxygen divalent, and carbon tetravalent, and carefully respecting the valencies of the component atoms.



$$\begin{array}{ccccccccc} & & H & & H & & & & \\ & & | & & | & & & & \\ H & — & C & — & C & — & O & — & H \\ & & | & & | & & & & \\ & & H & & H & & & & \end{array}$$

Ethyl alcohol.



$$\begin{array}{ccccccccc} & & H & & & & H & & \\ & & | & & & & | & & \\ H & — & C & — & O & — & C & — & H \\ & & | & & & & | & & \\ & & H & & & & H & & \end{array}$$

Methyl ether.

These examples illustrate the ordinary mode of expressing the constitution of molecules by means of constitutional formulæ, in which each atom is represented by the symbol of the element, and each unit of valency by a line joining the symbols. The constitution of a compound is ascertained by the exhaustive study of its chemical character, and in particular of the processes by which it can be prepared, of the changes which it can be caused to undergo through the action of heat or other agencies, and of the substances into which it can be converted. The solution of the problem is in some cases attended with much difficulty, but is also of the first importance, being in general the first step towards the synthesis of the compound. Whilst there are many compounds of which the constitution is still unknown, notably many of the alkaloids and of the highly complex substances found in the animal organism, and of which, therefore, the preparation in the laboratory cannot as yet be effected, still of the great majority of compounds it can be said that the way in which the atoms of the constituent elements are linked together in their molecules is no longer a mystery.

The views regarding the constitution of compounds which find expression in the ordinary constitutional formulæ were sufficient at first to explain very many observed cases of isomerism, but as the number[1] of organic compounds known to chemists increased through the rapid development of this branch of the science, instances soon began to accumulate of substances which occur in a larger number of isomeric forms than can be accounted for by the theory of atomic linkage. Thus it was found that tartaric acid occurs in several isomeric forms, which all have the same molecular constitution, but which differ in some of their physical properties, notably in the effect of their solutions on a ray of polarised light. The ordinary form rotates the plane of polarisation of the ray to the right hand, a second variety has an opposite effect, and a third is without action on the ray. In 1861 Pasteur made a discovery of great importance, namely, that on the crystals of the dextro-rotatory form of tartaric acid there are minute facets, which are absent from the crystals of the inactive form, which is known as racemic acid, and he subsequently found that by crystallising racemic acid in a particular way he obtained two sets of crystals, some identical with those of the dextro-rotatory acid and some the mirror images of these. When separated from each other and dissolved in water, each variety was found to rotate the plane of polarised light, the crystals with facets on the right corners being dextro-rotatory, and those with facets on the left corners being equally strongly laevo-rotatory. From these facts Pasteur drew the inference that the differences between the two varieties must be due to the different arrangement in space of the atoms composing their molecules. A few years later Wislicenus demonstrated the existence of three isomeric lactic acids, one of which was dextro-rotatory, another laevo-rotatory, and the third without action on a ray of polarised light. He showed that the three varieties had the same composition, expressed by the formula $C_3H_6O_3$, and the same molecular constitution, represented by the formula

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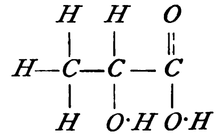
[1] More than 100,000 compounds of carbon have been described, and the number may be said to increase daily.



$$\begin{array}{ccccccc} & & H & & H & & O \\ & & | & & | & & \| \\ H & - & C & - & C & - & C \\ & & | & & | & & | \\ & & H & & O{\cdot}H & & O{\cdot}H \end{array}$$

and contended that he had fully proved the insufficiency of the ordinary method of expressing the constitution of compounds. Shortly afterwards van't Hoff and Le Bel pointed out, independently, the step needed to rid the atomic theory of those apparent anomalies. They indicated that the theory of atomic linkage, upon which the usual method of writing constitutional formulæ is based, has a weak point in so far as it makes the tacit assumption that the atoms within the molecule are all arranged in the same plane—that the molecule is, so to speak, spread out on a plane surface. All difficulties vanish if this assumption is set aside in favour of the more rational view that the molecule is extended in space of three dimensions. The arguments advanced by van't Hoff and

Le Bel form the basis of the subject known as stereo-chemistry, the branch of science which deals with the *configuration* of the molecule, that is, with the manner in which the atoms are distributed within the molecule in three-dimensional space. The form of isomerism which results from differences in the configuration of molecules, such as those of the three lactic acids, is known as stereo-isomerism. The theory may be stated in general terms. The simplest organic compound, methane, has a molecule composed of one carbon and four hydrogen atoms. According to the ordinary constitutional formula, the atoms of the molecule of methane are pictured as if all joined together in one plane (Fig. 1), whilst according to the new view the carbon atom is imagined as occupying the centre of a regular tetrahedron, the four hydrogen atoms being situated at the four apices (Fig. 2).

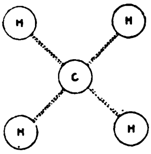


Fig. 1.

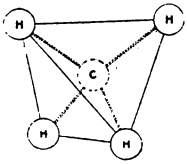


Fig. 2.

Suppose that three of the four hydrogen atoms of methane are replaced by three other atoms or groups of atoms different from each other, for example the groups CH_3, OH, and $COOH$, as in lactic acid. The carbon atom which was present in the methane molecule is in those new compounds attached to four different atoms or groups of atoms; such a carbon atom is termed asymmetric. By the help of the models it is easy to see that the groups of atoms within the molecule can be arranged in two different ways, giving two stereoisomeric molecules (Figs. 3 and 4), which differ only in that the one is the mirror image of the other; they are related in the same way as a right hand and a left hand. Those enantiomorphous molecules are composed of the same atoms linked together in the same way, that is, their constitution

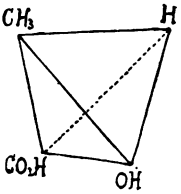


Fig. 3.

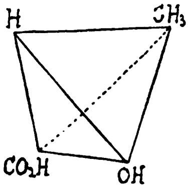
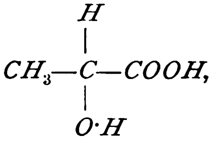
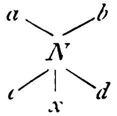
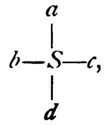
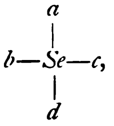
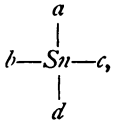


Fig. 4.

is the same, but the atoms within the molecules are distributed differently in space—their configuration is different. Any observable differences between two molecules thus related should consequently not be differences of an ordinary chemical nature, but differences involving merely a kind of chemical and physical right and left-handedness. If one of the molecules has the effect of rotating the plane of polarisation of a ray of polarised light through a given angle to the right hand, the other should have an equal but opposite effect. Now the lactic acid obtained from sour milk is optically inactive, but the isomeric acid extracted from flesh juice is dextro-rotatory. By suitable means the inactive form can be split up into two active forms, one dextro-rotatory to the same extent as the acid from flesh juice, the other equally strongly laevo-rotatory. The acid from sour milk has no action on a ray of polarised light, because it is a loose kind of compound of the active acids in equal proportions. Now the molecule of lactic acid contains an asymmetric carbon atom, as is apparent if the formula of the compound is written thus  $CH_3\text{—}\overset{\displaystyle H}{\underset{\displaystyle O{\cdot}H}{C}}\text{—}COOH,$ and therefore the isomerism between the two active forms can be explained on the assumption that they differ in configuration, the one being the mirror image of the other. All other instances of stereo-isomerism among carbon compounds can be explained by the theory of van't Hoff and Le Bel; it is in the case of substances containing an asymmetric carbon atom that the theory of atomic linkage fails to explain the observed facts, and it is just in these cases that the species of isomerism indicated by the solid models is found to correspond closely with the facts. Within recent years a considerable extension of the original theory of van't Hoff and Le Bel has become possible. Those investigators traced all cases of optical activity to the presence of an asymmetric carbon atom and deduced from their work the conclusion that the environment of the carbon atom in methane is a tetrahedral one. It is true that all the optically active substances which have as yet been obtained from natural sources owe their optical activity to the presence of asymmetric carbon atoms, but, by the application of appropriate methods to the investigation of synthetic materials, compounds have been prepared of which the optical activity is due to the presence of asymmetric atoms other than those of carbon. Thus nitrogen compounds (substituted ammonium salts) of the type  have been found to exist in dextro- and laevo-rotatory modifications, and the conclusion is necessarily drawn that optical activity is an attribute of the asymmetric pentavalent nitrogen atom as well as of the asymmetric tetravalent carbon atom. The optical activity of such compounds indicates that their molecules have an enantiomorphous configuration, and are extended in space of three dimensions; the exact nature of this configuration is not known, inasmuch as an arrangement in space of five groups is concerned, but the environment of the nitrogen atom in ammonium salts is certainly not a simple tetrahedral one. Moreover, it has been demonstrated that asymmetric tetravalent atoms of the elements sulphur, selenium, and tin also give rise to optical activity, optically active compounds of the types represented by the general formulæ  $\begin{array}{c} a \\ | \\ b—S—c \\ | \\ d \end{array}$,  $\begin{array}{c} a \\ | \\ b—Se—c \\ | \\ d \end{array}$, and  $\begin{array}{c} a \\ | \\ b—Sn—c \\ | \\ d \end{array}$, having been prepared. Thus some progress has been made towards obtaining a complete stereo-chemical scheme embracing all the elements.

The comparatively recent development of the branch of the science generally known as physical chemistry has led to the formation of many new ideas. Within the limits of a short paper, however, it is impossible to do more than refer to some of the important conclusions which have been arrived at by the study of the properties of solutions. When a solid is dissolved in a liquid the molecules of the solid become separated from one another to an extent depending upon the volume of the liquid, and gradually intermingle with the molecules of the solvent until finally a homogeneous mixture, termed a solution, is formed. The process is analogous to the mixing of gases with each other, and is known as diffusion. The pressure of a gas upon the walls of the vessel which contains it is believed to be produced by the impacts of the rapidly moving molecules against the walls. Since it is the motion of the gaseous molecules which produces pressure, the motion of the molecules of a dissolved substance, which causes them to diffuse through the space occupied by the solvent, must also produce pressure. This osmotic pressure, as it is called, can be measured, and it has been proved that in any given solution the osmotic pressure is directly proportional to the concentration and also to the absolute temperature of the solution. Now the pressure of a gas, at constant temperature, is directly proportional to the density or concentration of the gas, and, further, the pressure of a gas at constant volume is directly proportional to the absolute temperature. Thus the osmotic pressure of dissolved substances depends upon the volume and the temperature in the same way as the pressure of a gas does. As the osmotic pressure is in general independent of the nature of the solvent, it is determined by the number of molecules contained in unit volume of the solution, just as in the case of gases, and, moreover, experiment has shown that the osmotic pressure is exactly the same as the gaseous pressure which would be observed if the solvent could be removed, and the dissolved substance left filling the same space in the gaseous state at the same temperature. The similar behaviour of different gases when subjected to similar changes of temperature or pressure is explained by Avogadro's hypothesis that equal volumes of gases, when measured under the same conditions, contain equal numbers of molecules. The analogy between gaseous pressure and osmotic pressure can also be explained by the suggestion, put forward by van't Hoff, that solutions which have the same osmotic pressure at the same temperature, must contain in equal volumes equal numbers of dissolved molecules. It has been pointed out already that, taking Avogadro's rule for granted, the molecular weights of substances capable of being vaporised without decomposition can be found experimentally by measuring their vapour densities. From what has just been said it follows that the measurements of the osmotic pressures of solutions should enable us to determine the molecular weights of dissolved substances. Such measurements are difficult, but fortunately not necessary, for, as van't Hoff pointed out, very simple relations exist between the osmotic pressure of a solution and the lowering of the freezing point, and the raising of the boiling point of the solvent due to the presence of the dissolved substance. With the same solvent, the freezing point is lowered, or the boiling point raised, in proportion to the quantity of a dissolved substance present, if the solution is a dilute one. Further, with the same solvent, if dissolved substances are taken in quantities proportional to their molecular weights, the same lowering of freezing point or raising of boiling point is produced in each case. Thus it is possible to determine experimentally the molecular weight of any substance which will dissolve in a solvent of which the molecular depression of freezing point, or the molecular elevation of boiling point, is known, and a most valuable method of research is put into our hands.

In determining molecular weights by the vapour density method a certain number of substances are met with which apparently do not conform to Avogadro's rule. For example, the density of the vapour of ammonium chloride is just half of what it ought to be if the molecular composition of ammonium chloride is correctly represented by the formula NH_4Cl, as can otherwise be shown to be the case. Other substances show similarly abnormal vapour densities. To explain these results Deville suggested that when such substances are vaporised they split up into simpler substances, each of which of course has its own vapour density, and the density of the vapour will then be the mean of the densities of its components. Thus if ammonium chloride, NH_4Cl, be supposed to decompose into ammonia, NH_3, and hydrogen chloride, HCl, when converted into the gaseous state, the density of the supposed vapour of ammonium chloride will in reality be the mean of the densities of ammonia and of hydrogen chloride. The value calculated on this supposition agrees exactly with the experimental result. Deville gave the name *dissociation* to this kind of decomposition, when the products of decomposition formed by rise of temperature, reunite on cooling to form the original substance. It can be proved experimentally in the case of ammonium chloride, and also of many of the substances which exhibit abnormal vapour densities, that dissociation actually does take place. It has also been shown that dissociation is promoted by rise of temperature or fall of pressure, and reversed by fall of temperature or rise of pressure. The fact of dissociation having taken place when a substance is vaporised can be inferred in another way. At a given temperature the pressure of a given volume of a gas depends upon the number of molecules contained in the space occupied by the gas. If a molecule of a substance dissociates into two or more simpler molecules when the substance is converted into vapour, the pressure of a certain volume of the vapour at a given temperature must be proportionally greater than it would be if no dissociation had taken place. Experiment has shown that this is the case. Now it has been found that the osmotic pressures of aqueous solutions of certain substances (or strictly speaking, the depressions of the freezing points and elevations of the boiling points of these solutions) are greater than those calculated from the supposed molecular weights of the substances. If the solutions are sufficiently dilute the values of the osmotic pressure in each case reach a maximum, two, three, four, five or more times the calculated value, and diminish if the solutions are concentrated. If the analogy between gases and solutions is borne in mind, an explanation of these facts is naturally sought for in the supposition that if the osmotic pressure of a dissolved substance is greater than what would be expected from its known molecular weight, the molecules of the dissolved substance must have undergone dissociation into two or more simpler parts. Now in all such cases of abnormal osmotic pressure it is possible to conceive the dissolved substance as being divided into a number of separate portions, consisting of atoms, or groups of atoms, which corresponds with the number of times the observed osmotic pressure is greater than the calculated pressure. For example, the maximum osmotic pressures of solutions of sodium chloride, $NaCl$, strontium nitrate, $Sr\,(NO_3)_2$, and potassium ferricyanide, $K_3\,Fe\,(CN)_6$, are respectively two, three, and four times what would be expected from the formulæ of these salts; but the molecules of sodium chloride can be supposed to be divided into two parts, Na and Cl; those of strontium nitrate into three parts, Sr, NO_3, and NO_3; and those of potassium ferricyanide into four parts, K, K, K, and $Fe(CN)_6$. At first it is difficult to believe that such a dissociation of complex molecules could be effected simply by dissolution of the substances in water, but the suggestion put forward by Arrhenius removes the difficulty. He indicated the fact that all of the solutions which show this behaviour are conductors of electricity, whereas substances whose solutions do not conduct electricity have normal values of the osmotic pressure. Of course metals and some other substances also conduct electricity, but they are apparently unchanged by the passage of the electric current; on the other hand the passage of a current through an electrolytic conductor is attended by profound chemical changes. Comparatively few pure substances act as electrolytic conductors with the exception of fused salts. It was by the electrolysis of fused salts that many of the metals were first isolated, *e.g.*, sodium and potassium by Davy, whilst at the present time such metals as sodium, magnesium, and aluminium are prepared by this method; however, it is to solutions, and in particular to aqueous solutions, of electrolytes that our systematic knowledge of electrolysis is confined. Now the conductivity of an aqueous solution of an electrolyte is not a property either of the dissolved substance or of the solvent, but of the solution itself. Pure water is practically a non-conductor, liquefied hydrochloric acid also cannot be called an electrolyte, but a solution of hydrochloric acid in water is an excellent conductor; when a current of electricity flows through such a solution hydrogen is liberated at the cathode and chlorine at the anode. It is not every solvent which behaves like water; for example, chloroform does not conduct electricity, neither does a solution of hydrochloric acid in chloroform. The property of conducting electricity, moreover, depends not only on the nature of the solvent, but also on the nature of the dissolved substance. In general the only substances which exhibit conductivity in solution in any marked degree are salts, acids, and bases—precisely those substances whose solutions exhibit abnormal values of the osmotic pressure. Faraday discovered that the amount of decomposition of an electrolyte is proportional to the quantity of electricity passed through it, and that if an electric current flows simultaneously through solutions of different electrolytes the weights of the elements or groups of elements liberated at the electrodes are proportional to their chemical equivalents. There is here a direct proportionality between quantity of matter and quantity of electricity. In order to form a mental picture of what happens within an electrolytic solution during electrolysis, it must be assumed that matter travels along with the electricity; Faraday denoted the particles of matter which convey electricity through the solution by the term ion; the ions migrate from one pole to the other carrying their electrical charges, the negatively charged ions passing to the anode, the positively charged ions to the cathode. Now, according to Arrhenius, when an electrolyte is dissolved in water, or other dissociating liquids such as methyl or ethyl alcohol, ether, or acetone, the molecules of the electrolyte begin to undergo electrolytic dissociation or ionisation, that is to say, they begin to break down into electrically charged ions. The degree of dissociation depends upon the concentration of the solution, increasing with dilution until it reaches a maximum, when all the molecules are dissociated into ions, and decreasing with increasing concentration. Only those molecules which are dissociated into their ions play any part in the conduction of electricity, the undissociated molecules remaining idle. The conductivity of a given solution therefore depends upon the number of ions in the solution and the rate at which these ions move. The ions are supposed to be independent of each other, and should act as separate molecules if the independence is complete. It is therefore to be expected that solutions of electrolytes, in which a certain proportion of the dissolved molecules break down into ions, should exhibit exceptional behaviour when investigated as regards their osmotic pressure. As has been indicated, this is the case, and the hypothesis of electrolytic dissociation affords a satisfactory explanation of the anomalous behaviour of the substances. It also affords a simple explanation of a set of facts which are so familiar that they are usually accepted without any attempt to account for them, namely, the reactions of acids, bases, and salts in solution, which we now recognise as being, in general, the reactions of the ions into which these compounds dissociate electrolytically. Naturally the hypothesis has met with general acceptance.

Although compelled to omit all reference to many subjects of equal interest and importance I have attempted to outline, as briefly as possible, some of the salient features in the development of chemical theory during the nineteenth century, in such a way as to trace the gradual progress from the fundamental conceptions of Dalton to the views which are generally accepted at the present time. Throughout the whole of that period none of the essential features of Dalton's atomic theory were abandoned; it remained the foundation upon which all subsequent developments were based. The atoms were regarded as unalterable particles, capable indeed of being grouped together in an almost endless variety of ways, but remaining constant and unchanged throughout all the transformations of the molecules whose ultimate components they are. The opening of the present century, however, has been signalised by discoveries which appear to necessitate a modification in our conception of the atom, for in the elements of which radium is as yet the most remarkable example, we meet with substances whose atoms are apparently susceptible to a hitherto unknown, although not undreamt of, change, in the sense that they exhibit a marvellous tendency to break down into simpler particles. It is indeed going beyond my province even to mention this subject, but I feel justified in doing so because the discovery is fruitful of promise that when the history of the development of chemistry during the twentieth century comes to be written, it will be found that the record of achievement is even more brilliant and amazing than that of the century which has recently come to an end.

Some Observations on Primitive and Early Markets and Fairs. By Sir James D. Marwick, LL.D., F.R.S.E. Being a communication from the Historical and Philological Section.

[Read before the Society, 23rd March, 1904.]

Trade and commerce, in forms and by processes however rude, must have been originated and carried on in times antecedent to recorded history, and under conditions of which nothing is now known. When, therefore, a conception is sought to be formed as to how primitive men lived and acted, and conducted their interchanges of commodities, reference can only be made to the life and practices of races still savage, or semi-savage, as these have been observed by explorers in recent times. Living under conditions substantially similar to those of primeval man, and unaffected wholly, or to any great extent, by contact with civilised peoples, it may be assumed that the habits and modes of life of the ancients and moderns, under similar, or approximately similar circumstances, are not essentially different.

Assuming that conclusion to be legitimate, and applying it to the endeavour to form an approximate idea of how trade and commerce were, in their rude beginnings, prosecuted among primeval tribes and peoples, it is necessary to ascertain, from modern explorers and discoverers, how the rude races which they have visited and observed, conduct their barterings and sales. A few examples of this must suffice. These examples, however, illustrate a condition of circumstances in which trade or commerce was conducted by traders, or merchants, or middlemen. But it must be observed that a still earlier stage existed, in which barter or exchange was carried on between members of the same tribe or family, or by members of different tribes or families, and of which no records exist. Even as between members of the same tribe, an exchange of commodities must have become necessary. One man was able, either by natural aptitude or by practice, to produce better than his neighbour special articles of dress, or weapons of war or of the chase, or of general use, and by bartering these for commodities of which he stood in need, and which could be produced more easily and satisfactorily by others than by himself,[1] a system of useful trade was established, direct and immediate. By and bye the relations of the tribe were extended, and it became obvious that the interchange of the commodities which it could produce or provide, with those of another tribe near or distant, would be mutually advantageous. As civilisation advanced, therefore, the objects of exchange became more numerous, and the area of exchange more extended.

Reverting to the system of trade or exchange conducted by primitive races, as illustrated by the mode in which it is carried on by barbarous[2] or partially civilised peoples in modern times, Bancroft, in his work on Native Races says "Commercial exchanges were often made by deposits at particular spots at given times. In Russian Columbia for example, the merchant deposited his goods on the river bank and withdrew. When the Indian, after inspecting the deposit, placed beside it articles of what he considered equivalent value and retired. The merchant then returned, and, if satisfied with what the Indian had left, carried it away. If not satisfied he again withdrew, and, if the deposit was not increased, the merchant resumed possession of his goods.[3] In New Mexico again, when the Indians wished to trade with the Spanish soldiers of the Presidios, they erected little crosses along the road from Chihuàhua to Santa-Fè, and on these hung a leather pouch with a piece of venison. At the foot of each cross they placed buffalo hides to be exchanged for food, and in exchange for these the Spaniards placed salt meat at the foot of each cross.[4] The Redskins (North American Indians) acted somewhat similiarly in their trading transactions among themselves, under the protection of their chiefs. The caciques and warriors of two negotiating tribes began by exchanging presents; then they traded from wigwam to wigwam, sending in their goods for sale, and these were either returned, or equivalent value was rendered. In Chili the arrival of merchants was announced by the chief by the sound of trumpet, and the Indians thus summoned hastened to divide the goods among themselves. When the merchant was about to speedily in coinage bearing recognised impressions, and possessing recognised and generally accepted values.

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[1] Appendix A, p. 148. [2] Appendix B, p. 148.

[3] Native Races, I. 63, 64. Appendix C, p. 148.

[4] Humboldt, *Essai sur la Nouvelle Espagne*, I. ii., liv., III. c. viii. q.b. Letourneau, *Property, its Origin and Development*, p. 347.

In comparatively civilised districts, such as Timbuctoo (within the French sphere of influence in West Africa), money in specie is recognised, but is very rare and much sought after. At Kukana, in Nubia, between the Egyptian frontier and Khartoum, and between the Red Sea and the Lybian Desert, and in the whole of Eastern Africa, including Abyssinia, the recognised money is the Austrian thaler, impressed with the head of Maria Theresa. It comes from Egypt, or by way of Egypt, and is of great assistance in commercial transactions. But metal money has not yet penetrated into the regions of the Great Lakes.

In the petty barbarous monarchies of Central Africa, says Letourneau,[1] where Berber and Negro blood are largely mingled, there is an active trade in slaves, commodities, stuffs, etc. There are even regular markets, sometimes daily, and these are sometimes fortified to protect the merchant from sudden attacks. But the petty kings and chiefs levy dues, and sometimes heavily on the wares; and at Kano in the Houssa the governor appropriates two-thirds of the fruits brought to market. Kano, it also appears has a trading connection with distant countries. The republican Kabyles, in the North East of Algeria, also have markets which belong to the tribe, and to each market sale-masters are appointed, but the markets are free of all dues, save for the tribal school *mâmera* where there is one. Moreover the market ground is declared neutral, and placed under the *ânaia* of the proprietors; even in time of war is it possible to go to and from it with impunity. Any offence committed against the market is a violation of the public *anaia* and it is punished on the spot with extraordinary severity; for example the smallest theft entails immediate stoning.

As regards the invention of money, the peoples of Central America have gone through much the same process as the African tribes. Among the Chinooks (an Indian tribe in British Columbia) money is a shell, strung in chains, the value—the length being the same—increasing with the size of the shell.

In the Mongol and Mongoloid World of Oceania and Asia, money was evolved very much in the same way as in Africa.

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[1] Letourneau, ut supra, p. 349.

In Polynesia, in the time of Cook, everything could be bought for red feathers, or better still, nails. In certain islands in Malaysia (or Eastern Archipelago), not long ago, every thing was to be had for iron of which the natives made tools and arms. Even now, in the Ke (Kei or Key) Islands (a group of two principal and some smaller islands in the Malay Archipelago, west of New Guinea) money is unknown; knives, clothes, or arrak are the only means of exchange. But the most civilised Malay states have metal money. Formerly, in the kingdom Queda (Achin, in the North of Sumatra), the king obtained tin from his mines, and from it manufactured pieces of money, each weighing a pound, and "worth seven sous," says an old missionary. Besides, he had very minute gold coins struck, an eighth of an inch in diameter, and engraved with Arabic letters. A miniature copper coinage also circulated amongst the people. In Java, before the Dutch colonies were established, the current coin was the circular Chinese *sapee*, pierced with a hole in the centre, and weighing seven drams. It is still the only metal coin of China, at all events the only one struck. These *sapees* are strung together by hundreds and thousands. A thousand thus strung together make a band, and are worth about four shillings. The invention of the *sapees* in China dates back, it is said, 2,600 years before Christ. But at the same time the Chinese make use of silver in bullion as a form of money. Pieces are cut off as occasion demands and weighed. The Chinese *tael* simply represents a Chinese ounce of silver (37 gr. 796).

Mr. Stanley found markets and fairs in places where there was no ground for believing that the white man had previously trod. His book "Through the Dark Continent" contains information on the subject. It describes fairs in Kagehy on the southern border of Victoria Nyanza.[1] Ujiji, on Lake Tanganyika, where there is a great market. Nyangwe on the eastern side of the Lualaba, Usoga, Ngombo, and other places on the banks of the Livingstone river along its whole course.

After trade had advanced beyond the simple stage of barter as between members of the same tribe, or as between them and members of other tribes, middlemen or traders came into operation.[1] These made it their business to carry the products of one district or country into other districts or countries; and thus a more elaborate system of exchange was introduced which, in its development proved advantageous to all. This led to two great advances—the establishment of recognised media of exchange, and the establishment of great trade routes. It has been noticed that in primitive and barbarous countries shells were used, in others beads and trinkets, and in modern times, unhappily, gunpowder and intoxicating drinks have been introduced by the white man. But in a more advanced condition of trade, such as that conducted by the Greeks and Romans, the recognised standard of value was the cow, superseded by metal money. As if, however, to perpetuate the remembrance of the earlier currency, the image of the cow was stamped upon the metal coinage.

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[1] Stanley. Edition of 1890, p. 97.

Some idea of the methods by which trade was conducted in early times by semi-civilized people may also be obtained by looking at the methods, as still in operation, in the conduct of the extensive systems of trade by which Europe in modern times has been brought into communication with the interior of Africa across the Sahara. European commodities transmitted through Tunis, for example, are carried by native merchants to a spot where they are purchased by merchants from Gladamis, and are there associated with commodities from Tripoli, Algiers, and Egypt. After changing hands there, they are conveyed by the great annual caravan to Ghat where they are exchanged for Soudanese goods. That is the Eastern route of trade. On the Western route a similar course is followed. Goods from Morocco and Algeria are carried by native tribes to Talifet, Methli, etc., and placed in the markets of El-Golea; thence they are conveyed to markets in the Oasis of Twat, and thence to Timbuctoo. These goods are generally accompanied throughout their transit by merchants of Gladamis. The commerce conducted by these two routes is different in character. Tunis and Tripoli export chiefly objects of luxury from Europe—as silk and other articles of mercery; pearls, cloves, cinnamon, perfumery, paper, cloth, etc. Morocco, on the other hand, furnishes objects of more immediate necessity—such as grain, sheep, and wool. The staple commodities brought back from Soudan are negro slaves, gold dust, elephants' teeth, senna, ostrich feathers, buffalo hides, the blue cotton made in the negro country, gour-nuts for staining the teeth, etc., the two last articles however, do not reach the northern states, but are disposed of among the inhabitants of the desert; and it is to be noted that the oases are places of consumption and production as well as of exchange: they absorb a large portion of the merchandise both of the north and south on its way; while to the former they add salt and natrona (nitre), and to the latter dates and fine woollen cloth.

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[1] Appendix E, p. 149.

Each considerable town of the desert becomes periodically a *sook* or fair. An English traveller who witnessed that of Ghat about 1846, states the number of merchants who arrived from various parts to have been about 500, the camels 1,050, the slaves 1,000. The value of the slaves, elephants teeth and senna, which were the staple commodities from the south, was estimated at about £60,000, which would be doubled on their arrival at European markets. Besides these, were ostrich feathers, hides, utensils of Soudan, manufactures used in the Sahara, and the dark blue calico which clothes half the inhabitants of the desert. From Europe there were bracelets, beads, looking glasses, razors, sword-blades, needles, paper, silks and cottons of gay colours, but everything of the poorest quality. Very little gold was to be seen. What did appear was chiefly in the form of female ornaments, rudely fashioned, but of the purest material. These were tied up in filthy pieces of rag, and deposited, during their journeyings, in the bosom or turban of the merchant. But most of the gold which is found in the interior of Africa is carried either to Morocco or to the European factories on the West Coast.

Most of the traffic of the Desert is effected by barter, and very little specie is used. That which is most circulated in the North is the money of Tunis, which is current as far as the Oases of Twat and Fezzan. Further South some Spanish money is transmitted through Morocco, and a few Turkish coins, which naturally find their way from Tripoli; but the latter are generally disliked. Among the Negro tribes the shell currency, known as *couries* is used. Every year the English pour into the country, by Guinea, nearly a hundred tons of couries from Bengal, where they bear about one tenth part of the value that they do in Soudan.

The means of travelling in this part of the world are wholly different from those which nature and civilisation have bestowed on Europe. The largest rivers are unnavigable at a few miles from their mouths; the highway and the canal, are things unknown. The Arab roads in the North are mere tracks marked on the sod by the naked feet of men, and the tread of horses or mules. They are so narrow that two persons cannot walk on them abreast; consequently, if travellers or caravans meet, the one takes to the right and the other to the left, so that two tracks are formed; and the more any particular route is frequented, the more paths may be found, sometimes running parallel and sometimes crossing each other. If an Arab is turned out of his track for a time he hastens back to it as soon as possible; hence the intersections. On the other hand, if a caravan is very large, it divides into two or three files, preserving equal distances; and so forms the parallel paths. As the custom of proceeding in single file, has produced these narrow tracks so have these in turn perpetuated the custom; in the Tell the natives may be seen travelling in single file on roads forty-eight feet broad, constructed by their European conquerors, the traçes of the national locomotion being thus impressed on the highways opened by civilisation.[1]

It is noticeable that even nomad pastoral races had commercial relations with other peoples in very early times, and that silver and gold formed a portion of their wealth. Abraham, for example, was rich, we are told not only in cattle but in silver and gold,[2] and could send Rebekah and her relatives a ring, bracelets and jewels of gold and silver, and raiment and other precious things.[3] The surrounding nations and peoples of his time were also in possession of the precious metals—probably in a coined state—and it is recorded that Abimelec, king of Gerar, gave Abraham a thousand pieces of silver.[4] The practice of merchandise was also then understood, for, as the result of his negotiations with the children of Heth for a burying place for Sarah his wife, Abraham weighed out to Ephron four hundred shekels of silver "current money with the merchant."[5] When Jacob bought from Hamer, Schechem's father, a parcel of a field, he paid for it "one hundred pieces of money," or "lambs"—

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[1] Chambers, Papers ix. The Deserts of Africa, pp. 25-27.

[2] Genesis xiii. 2. [3] Ibid, xxiv. 22, 53. [4] Ibid, xx. 16.

[5] Ibid, xxiii. 16. We are not told whither the shekels represented bullion or coined money. But it is to be observed that the word "Merchant" indicates the existence at that time of merchants as a recognised class, using money of a standard fixed by their usage.

each piece being marked by a lamb.[1] So too—and as indicative of early customs—whatever opinion may be entertained otherwise of the book of Job—it is stated that, after Job's troubles, his brethren and sisters and acquaintances comforted him, and "every man gave him a piece of money and a ring of gold."[2]

Of the routes established to meet the requirements of a diffused trade, probably one of the earliest centres, from which others radiated, was that from Egypt, where traders to the east and west congregated, and where, on the banks of the Nile, the civilisation of the ancient world found a befitting centre. Bukhara, which still remains the most important commercial town in central Asia—nearly eight miles in circumference, and possessing it is said 360 Mosques—was at a very early period a centre of trade at which the products of the western regions of Africa met the merchandise of the west. The route of a caravan westward, laden with silks and precious stones, ivory, pearls, and spices, was by way of Herat in Afghanistan and Ecbatana in Persia. For the conveyance of these commodities over inland routes the camel was employed, becoming, as it was called, the "ship of the desert," as in the trade with India the elephant did the corresponding work.

Where available, the great river systems of the various trading countries became highways of trade. The Nile, the Tigris, the Euphrates, the Indus and the Ganges, in early times were, as the Rhone, the Rhine, the Po, the Danube, the Don, and the Volga, in later and modern times are, made available for river traffic. But commercial enterprise, even in these early periods, needed the means of wider diffusion than river systems afforded, and ships were required. So the Persian Gulf, the Mediterranean, and the wide waters beyond, had to bear on their bosoms the crafts of the developing trade.

In the conduct and development of this trade, markets and fairs must have been established at an early period in suitable centres, and their position must have been largely determined either by religion, or pleasure, or by whatever led to certain spots being used for great periodical gatherings. Among the circumstances which largely determined the position of these markets and fairs in early times were the intersection of great lines of road, the existence of fords across important rivers, or an advantageous position at the mouth of an estuary, or on the coast line.[1]

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[1] Genesis xxiii. 19.

[2] Job xlii. 11.

Reference may now be made to trade and merchandise as these existed in Egypt, Assyria, Babylonia, Arabia, among the Hebrews, in Phœnicia and Etruria.

The situation of Egypt in a fruitful valley through which the Nile flows, appears to have been the favoured spot on which ancient civilisation settled in an uncertain but fabulously remote past. With its heat moderated by its great river, the annual overflow of which submerged extensive tracts of land on either side, and enriched and fructifyed what it submerged, it was occupied by an industrious, and in many respects, highly organised people. The Homeric poems, of a date possibly 1,200 B C., describe this favoured land, its far flowing Zeus-born river, its beautiful fields and cities, its princes who fought from chariots, its city of Thebes with a hundred gates, from each of which went forth 200 men with horses and chariots. Hebrew tradition also, it is said, gives at a much earlier date accounts of the court and civil life of this people, and of its cities—the foundation of which they attribute to about 1,550 B.C. It is unnecessary to consider here the claims to a much greater antiquity put forward by the priestly class, as given by Herodotus who visited the country about the middle of the fifth century B.C., or by Diodorus who followed him about 400 years afterwards.

This, however, seems certain that although the Egyptians—with a lofty sense of their superior purity and culture, despised outside nations, and rarely travelled into other lands than their own, they tolerated, if not encouraged, trade with peoples who could interchange commodities with them. They satisfied these nations by restricting importation to specified places. That their import and export trade was established long before recorded history appears obvious, for, when reference to trade is made, it appears as developed and recognised. Duncker[2] says that, notwithstanding their exclusiveness, "Egypt was the centre of a considerable trade. They caused the products which they needed to be brought to them, without themselves going to seek them. Egypt required wood for the building of houses and ships, brass, ivory, slaves and incense. Even 1500 B.C., Arabian caravans carried the products of the south coast of Arabia to Syria and Egypt. The wandering tribes of Lybia, Syria, and Arabia required corn, weapons, utensils and implements, and these they could buy in Egypt. Then, at a later period, came the trade of the Phœnicians with Egypt. They could bring wood from the forests of Lebanon, wine, oil, slaves, amber and tin, and exchange them for glass, drugs — which Egypt produced in great quantities — fish and fabrics, linen and material prepared from the papyrus. Horses also and chariots were brought as articles of trade from Egypt to Syria about the year 1,000 B C.[1]

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[1] Appendix F, p. 149.

[2] History of Antiquity, (1877), p. 1, 226.

About, it is said, 1322 B.C. Rameses II. (the Great)[2] who is sometimes identified with the Pharoah of the oppression, is said to have established a fleet on the Mediterranean, and Dr Budge states, that about 1200 B.C., Rameses III., who is sometimes identified with the Pharoah of the Exodus (though both identifications are open to question), restarted the copper mines in the Sinaitic Peninsula, and sent envoys from Egypt to work them. Thence metal ingots were brought in ships to the port of Egypt in the Red Sea, whence they were conveyed by asses into upper Egypt. The turquoise mines in the same peninsula were also worked by Egyptian officers, and fine stones were conveyed to the king. This king also made great efforts to secure the success of his trading expeditions, to maintain old markets, and develop new ones.[3]

Frequent references are made in the Bible to the trading relations of Egypt, conducted largely by caravans, over great lines of intercommunication, or borne by ships. Of such caravans there is an illustration in the travelling company of Ishmaelites, "bearing spicery, balm, myrrh, from Gilead to Egypt," to which Joseph was sold by his brethren. The conditions of early traffic are also indicated by the resort of "all countries" to Egypt to buy corn during the great famine in the time of Joseph,[4] and by the journeys of the sons of Jacob to obtain food supplies, carrying with them money to pay for what they received.[1]

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[1] 1 Kings x. 28, 29; 2 Chronicles i. 16, 17; ix. 28.

[2] Known by the Greeks as Sesostris.

[3] History of Egypt (1902), v. 160.

[4] Genesis xli. 57.

The early development of trade and commerce in Egypt seems to have been looked at with little favour by the priestly class, which, cherishing a lofty superiority over other peoples, and shunning association with them, forbade their countrymen to go to sea or to take part in caravans, and declared the principal beasts of burden—the camel and the ass—to be unclean. The points at which alone foreign caravans were required to enter the country, or to stop, were prescribed. Foreign ships might only enter Egypt by the Canopic branch of the Nile, and exchanges of merchandise could only be made on the little island of Pharos. To land elsewhere risked the punishment of slavery or death. These prohibitions were not relaxed or removed till about the seventh century B.C. But, as has been said, the love of gain is tenacious, and in Egypt, under the Pharaohs, as elsewhere, merchants in the end organised and carried on an important export trade in cereals, stuffs, glass, pottery, etc.[2]

The country watered by the Euphrates and the Tigris was the site of two great empires of the ancient world—Assyria and Babylonia. Of the former Nineveh[3] (the modern Kouyunjik) on the east bank of the Tigris was the capital, and of the latter Babylon, situated on both banks of the Euphrates, and represented now, it is believed, by the town of Hillah.

Of the Assyrian Empire little is known, and that little has relation mainly to the later portions of Assyrian history. The earliest reference to it is in the tenth chapter of Genesis, and is understood to imply that the country around Babel (afterwards called Babylonia) was the older empire, and that Assyria was a colony or dependency of the original kingdom of Nimrod "the mighty hunter." No subsequent allusion to Assyria appears to be made till 769 B.C., when mention is made of a succession of kings of the country, after the last of whom (Nebuchodonoser) no king of Assyria proper is referred to.

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[1] Genesis, xlii. 25; xliv. 2.

[2] Diodorus, I. 67 q., by Letourneau, p. 349.

[3] One of the primeval cities mentioned in Genesis, x. 11.

In such a paper as this it is scarcely possible to discriminate between the trade relations of the two countries which indeed are often comprehended under the name "Babylonia," including Assyria, Chaldea, and Babylonia. So Professor Sayce writing on Babylonia says:—Of the Chaldeans it is emphatically said that "their cry was in their ships," and we have many indications of early commerce with the southern coast of Arabia. The trade of Assyria on the other hand was wholly overland; and its first fleet was the one built by Phœnician captives for Sennacherib when pursuing the fugitive Chaldeans through the Persian Gulf. Like the Jews, however, the Assyrians showed an aptitude for trade from the very first. The earliest Semitic settlements in Babylonia seem to have been mainly for commercial purposes, and their career there may be compared with that of the English in India. In the twelfth century B.C, the trading spirit had so thoroughly pervaded them that not only were objects of utility and art a marketable commodity, but we find Tiglarth-Pileser I. bringing trees from the countries he had overrun, and acclimatising them in Assyria. The fullest development of business and commerce, however, does not show itself until the eighth and seventh centuries B.C., when Nineveh was a busy centre of trade. Sidon and Tyre had been ruined by the Assyrian kings—indeed it is very possible that the obstinate wars with the Phœnician cities had their origin in commercial jealously, and trade had accordingly transferred itself to Carchemish.[1] The maneh of Carchemish became the standard of weight, Aramaic the common language of trade. The interest on money was usually at 4 per cent., but sometimes, more especially when objects like iron were borrowed, 3 per cent. Payment might still be made in kind; but more ordinarily in bars of the three chief metals, which were weighed, though mention of coined money also occurs. Houses could be let on lease, and the deed, which conveyed them gave a careful inventory of the property and its appurtenances. Commercial relations extended from India on the one side, whence came ivory and the teak found at Mugheir which Sennacherib probably means by "wood of Sinda," to the tin islands of Cornwall on the other.[2]

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[1] The place thus named in the Bible is probably that referred to by ancient writers as Circesium, now called *Karkisia* at the junction of the *Khabur* with the Euphrates.

[2] Article "Babylonia" Encyclopædia Brittanica.

In the earlier periods of Assyrian history, while its people were comparatively poor and uncorrupted, and cherished simple martial virtues, they conquered Babylonia and cultivated a lucrative trade with the east and west. Enriched by that trade Nineveh became the splendid capital of a great monarchy, supplanting Assur. But, as in the case of other nations, success and riches enervated the people, who succumbed to habits of sensuality and sloth. The Babylonians and neighbouring races who had been conquered by the Assyrians saw their opportunity, and stimulated by the wealth of their former masters, rose against Assyria and conquered it. Thus, between 625 and 609 B.C., the Babylonians and the allied Medes were enabled to raze Nineveh to the ground, and to apportion the old empire of Assyria.

Of the history and culture of the Assyrians, the discoveries of comparatively recent times, resulting from the excavations on the site of Nineveh by Botta, Layard, Rassam, and Smith, throw remarkable light, and evidence similarity between its husbandry, building, weaving, dyeing, and methods of trade with those of Egypt. Assyria could only be made fertile by an extensive system of irrigation conducted by means of reservoirs and canals, the remains of which, as well as of its great buildings, excite the admiration of modern travellers. So watered, its soil was most productive. Corn grew luxuriantly, and had to be mown twice a year.

Dates, wine, vinegar, and sago, were also abundant. What has further to be said as to Assyria may be concluded in the words of Canon Rawlinson. The art of Assyria, he says, has every appearance of thorough and entire nationality, but it is impossible to feel sure that her manufactures were in the same sense absolutely her own. The practice of borrowing skilled workmen from the conquered states would introduce into Nineveh and the other royal cities the fabrics of every region which acknowledged the Assyrian sway, and plunder, tribute and commerce would unite to enrich them with the choicest products of all civilised countries. Still, judging by the analogy of modern times, it seems most reasonable to suppose that the bulk of the manufactured goods consumed in the country would be of home growth. Hence we may fairly assume that the vases, jars, bronzes, glass bottles, carved ornaments in ivory and mother-of-pearl, engraved gems, bells, dishes, ear-rings, arms, working implements, etc., which have been found at Nimrod, Khorsabad and Kouyunjik, are mainly the handiwork of the Assyrians. It has been conjectured that the rich garments represented as worn by the kings and others were the product of Babylon, always famous for its tissues. But even this is uncertain, and they are perhaps as likely to have been of home manufacture. At any rate, the bulk of the ornaments, utensils, etc., may be regarded as native products. These are almost invariably of elegant form, and indicate a considerable knowledge of metallurgy and other arts, as well as refined taste. Among them are some which anticipate inventions believed till lately to have been modern. Transparent glass (which, however, was known also in ancient Egypt) is one of them. But the most remarkable of all is the lens, discovered at Nimrod, of the use of which as a magnifying agent there is abundant proof. If it be added to this that the buildings of the Assyrians show them to have been well acquainted with the principle of the arch, that they constructed aqueducts and drains, that they knew the use of the lever and the roller, that they understood the arts of inlaying, enamelling, and overlaying with metals, and that they cut gems with the greatest skill and finish, it will be apparent that their civilisation equalled that of almost any ancient country, and that it did not fall immeasurably behind the boasted achievements of the moderns.[1]

Babylonia[2] has ever been one of the most fertile spots in Western Africa. This fertility—promoted, as was that of Assyria, by a splendid system of artificial irrigation—produced not only rich crops of corn and other cereals, but various kinds of other fruits, semsame, cucumbers, melons, onions and garlic. The conditions of the social life of its people were also remarkable. And the knowledge of the ruling caste—the Chaldeans—had for that age of the world an extensive range. They were its astrologers, seers, and soothsayers. They were acquainted with the motions of the sun. moon, and five planets, the signs of the zodiac, the calculation of eclipses, and the division of the year into twelve months. The sun-dial and the water clock were used by them for computing time, and their systems of weights and measures was the basis of the Roman standards. The explorations of modern travellers and explorers have also revealed the high proficiency which this remarkable people had attained in art and manufacture, and their tablets refer among others to the trades which they carried on as weavers, dyers, potters, smiths, builders and carpenters. Commerce, too, was conducted by caravans with Bactria, Persia and Media, as far as India, and by shipping with Arabia.

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[1] History of Herodotus, Essay vii., vol. I., pp. 511, 512.

[2] Stretching along both sides of the Euphrates and also of the Tigris down to the Persian Gulf.

A recent writer thus describes the advantages which Babylon possessed for trade. The city was placed in the highway of the primitive land-trade east and west, and on its waters were made the first known attempts at river traffic. Food, produced in abundance at scarcely any cost of labour, was ready for traders in exchange for Chinese silks, Indian gems and spices, Bactrian gold and gold dust, and Western silver and wine. At home textile manufactures of wool, linen, and cotton, were carried to great perfection. *Sindones*, as some remarkably fine and beautifully dyed cotton fabrics were called, were so costly as to be restricted to royal use. Brilliant tapestries, upon which the zoology of India was embroidered, were coveted by princes for the choicest hangings of their palaces and harems, and from these the west received its first notions of Indian natural history. Carpets and coverlets from Babylonian looms were treasures more precious than gold. Borsippa[1] is mentioned as famous for the finest linen and cotton fabrics, but manufactures generally were carried on within the precincts of the capital. The dye stuffs were the Tyrian purple obtained from Phœnicia, Indian lac—the precursor of cochineal, and some other tropical products. The production of articles of luxury of great value also employed the Babylonians. Their parching climate rendered the use of cooling perfumed waters universal. They were expert in the art of engraving stones for seals, and they cut the gems of India for signet rings and jewellery. The first boats used for navigating the Tigris and Euphrates were rude coracles of light wood covered with skins. Such vessels are sculptured on the Assyrian monuments, and under the name of *keleks* continue to be used on both rivers for the transport of goods. By such means the wine and oil of Armenia, and commodities from the borders of the Mediterranean reached Theipsacus, a station between Babylon and Aleppo, on the upper course of the Euphrates, where the merchandise was again transferred to caravans and conveyed to the capital, whence it was distributed along various divergent routes. . . . Like the Egyptians, the Babylonians feared the sea, and left its navigation entirely to the daring and skill of the Phœnicians, who founded the ports in the Persian Gulf, Gerrha, coast, Tylos and Arados. But profuse wealth finally led to moral corruption on the part of the rulers, and invited aggression. Cyrus laid seige to Babylon, diverted the course of the Euphrates, and entered the city by the bed of the river during a nocturnal feast B.C. 538. Thus it sank to the level of the third capital of the Persian kingdom, Susa and Ecbatana ranking higher.[1]

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[1] Which was probably a suburb of Babylon.

On these ancient peoples—the Assyrians, Babylonians and Chaldeans—the discovery of their cunieform records by Layard and Botta have thrown a flood of light, and their complete decipherment and correct interpretation of them and such others as may yet be found, may, in the words of Mr Vaux of the British Museum, enable more to be known of the early history of Assyria than is at present known of any other eastern nation. All that has yet been done, he adds, appears to show that the mounds of ancient Assyria ascend to a very early period. That many towns, known from other sources to have been of very ancient foundation, have been recognised upon the inscriptions, and that it is quite clear that the ruling city Ninus, and the kings resident in it, possessed a very extensive empire at least as early as the fifteenth century B.C.

At Tylos, an island in the Persian Gulf [off the coast of Arabia], superior cotton was cultivated, teak oak was felled, and the banks produced pearls superior in hardness and beauty to those of Ceylon. Maskat, Djulvar and Ormuz shared in this commerce. Between these cities and India an active maritime commerce sprang up, and the port of Gerrha, also on the Persian Gulf, became the starting point of a caravan route across the Arabian desert. Through Bactria (one of the oldest cities in the world still called by Orientals "the Mother of Cities"), came Indian produce, cotton, silk and wool, both raw and manufactured, and large dogs trained for hunting. Media and Hyrcania supplied timber of various kinds; Scythia, skins; Egypt, flax, cattle, horses and mules; the enterprising Phœnicians sent from the Jewish ports of Elath and Ezion-Geber the valuable commodities procured from the shores of the Red Sea, and their own store houses contributed to the wealth of the Western World.

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[1] Growth and Vicissitudes of Commerce by John Yeates, LL.D. pp. 25-28.

Notwithstanding its proximity to the sea, a large portion of the Peninsula of Arabia is dry, parched, and unproductive, but in extensive districts wheat, barley, millet, palms, tobacco, indigo, cotton, sugar, tamarinds, coffee, senna, and many aromatic and spice plants—such as balsam, aloe, myrrh and frankincense—are produced. In the country, iron, copper, lead, coal, basalt and asphaltum are found, and various precious stones, emerald, cornelian, agate, and onyx. From the Persian Gulf also pearls are drawn. The position of the country between the valleys of the Nile and the Euphrates and Tigris brought the Arab tribes who wandered in these river valleys in early connection with Egypt and Babylon, and between them a system of barter was established. The Arabs required corn, implements, and weapons; Egypt and Babylon needed horses, sheep, goats, and camels. The requirements of both could be met by a system of exchange, which extended on the part of the Arabs to the costly spices and perfumes which their country produced. In the conduct of such trade between Arabia and Egypt, caravans of Ishmaelites, with camels carrying spices, balsam and laudanum were engaged in the twentieth century B.C. Duncker says that the need which Egypt felt to obtain the products of South Arabia is strikingly shown by the anxiety of the Egyptians to establish a direct route over the Arabian Gulf. The canal which Ramesis II. began to make towards the gulf, he says, could have had no other object than to facilitate the communication between the Nile and the coast of South Arabia and East Africa by the Red Sea. Under Ramesis III. (1269-1244 B.C.), a great fleet is said to have sailed for a second time to Nator, and to have returned to Coptus with the tribute of these lands and a rich freight. The need of incense was not less in Babylon than in Egypt. The preparation of ointments was a main branch of Babylonian industry.

The carrying trade between South Arabia, Egypt, Syria and Mesopotamia must have increased when the cities of the Phœnicians on the Syrian coast became centres of a trade which carried the manufactures of Babylonia, as well as the products of their own industry, over the sea to the West, and when the tribes of Greece and Italy began to desire the incense and spices of Arabia. And it was not only the products of South Arabia which the Arabs brought to Syria, Egypt, and Babylonia, but also those of the South coast of Africa, and even of India. At the beginning of the second century B.C., the island Dioscoridis off the south coast of Somali, which was known to the West as the Land of Cinnamon, formed the centre of the trade between Egypt, South Arabia, and India. To this island the ships of the Indians brought the products of their land.

In the first instance the Arabs transported the goods from South Arabia to the Euphrates and the Nile on their camels, and afterwards it lay with them to permit or refuse a passage for the caravans of the Babylonians and Phœnicians.

Soon after the year 2000 B.C., the tribes of South Arabia appear to have delivered their spices to the Egyptians, Syrians, and Babylonians, and their incense which Eastern nations, and in time Western nations also, burned upon the altars of their gods. Then they imported the products of the opposite shore of Africa, a region no less fruitful than South Arabia, and at length the ships of the Indians brought to them the products of the Indus and the Ganges. Thus South Arabia not only exported her own fruits, she became the central mart of East African and Indian products, the point of connection between Eastern and Western Asia. Owing to the fertility of their valleys and terraces, and their old and extensive trade, the tribes of the South soon acquired a more fixed form of constitution and a more advanced civilisation. Numerous remains of magnificent stone structures, ruins of aqueducts, canals, basins and dams, built with the object of preserving and collecting the water which streamed down the terraces of the mountains and in the valleys, still excite the astonishment of travellers for the excellence of the plan as well as for the strength of the masonry.[1]

Originally the Hebrews were a pastoral people, but after their conquest of Canaan they changed their pastoral into an agricultural life, and cereals, wine and fruit were their chief sources of wealth. When, accordingly, skilled industrial labour was needed, foreign workmen were employed. Commerce was at first discouraged by them on the ground, apparently, that the relations which it would have established with other nations would have compromised the purity of their own exclusive religion. But as the taste for luxury grew, this exclusiveness became less pronounced, and in the time of Solomon the Hebrews engaged freely in commercial relations with other nations. Following upon his alliance with Hiram, King of Tyre, an active trade was established between Jerusalem and the Phœnician cities. Joppa was opened as a port, and the precious materials for the temple were conveyed by way of it to Jerusalem. Solomon possessed vessels which left the port of Ezion-Geber, on the Red Sea, and he shared with the Phœnicians the trade with Ophir and Sheba, Arabia Felix, Ceylon, and India. Elath (now known as Aelana) and Ezion-Geber (known as Berenice) were filled with merchant ships, built at Solomon's expense and manned by Phœnicians, and Solomon himself visited the scene of the ship-building on the Red Sea. Jehosaphat at a later date was greatly interested in the Red Sea trade of the East.[1]

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[1] History of Antiquity by Duncker, I., 318-322.

The Hebrews were the first people to invent the bill of exchange, and ultimately the temple at Jerusalem was used as a bank of deposit, in which Jews from all parts of the world stored their precious metals. So when Heliodorus is said to have been sent by Seleucus, King of Syria, to carry off the treasure there deposited nearly two centuries B.C., the High Priest told him that it consisted wholly of deposits.[2] Mammon, the god of bankers, says Letourneau, had chosen the Holy of Holies as his dwelling place.

Centuries before Rome existed, a civilization was developed in Italy from which the subsequent mistress of the world borrowed her first laws, institutions and religious ceremonies. The evidences of that civilization have been found in the sepulchres of Etruria, mainly in the region now known as Tuscany, and in the portions of the Papal dominions lying to the north of the Tiber. The cities which existed in that territory, with all their adjuncts of roads, and drains, and tunnels, have long since well nigh disappeared, and what can now be deduced concerning them and their habits and general culture has to be deduced—as so much of Egyptian civilization has to be learned—from their tombs and what these contain.[1] These still afford evidences of the physical civilisation of the Etruscans—of their proficiency in the art of modelling in clay, of casting and chiselling in bronze, of working in gold and silver, of carving in wood and bronze, of engraving on precious stones, and of painting on walls and vases. The culture of which these arts are the indication existed before the nations of Greece, struggling for very existence, had given to the world their realised conceptions of the beautiful in art. In their early day, moreover, they were pre-eminent in commerce as in agriculture. Their fields, well cultured, yielded rich harvests of wine, corn, and olives, and their merchants promoted an important trade with Greece, Egypt, and Carthage, and established a trade by ships which navigated the Italian seas. Their system of coinage, too, says a writer, with that of weights and measures, is deserving of admiration. They knew how to draw from their mines the metals which they wrought so admirably. Even in military tactics they excelled ; for though it was not until pressed into the service of Rome that the Etruscan Phalanx became formidable to the liberties of surrounding nations, the armies of Etruria, in the days of her independence, were scientifically organised, regularly paid, and well disciplined.

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[1] History of Ancient Civilisation, by Verschoyle, pp. 79-80.

[2] 2 Maccabus, III. 10

Yielding to the inexorable force of circumstances, however, the civilization of Etruria had to give place to that of Rome, which, after playing its mighty part in the world's history, had, in like manner, to succumb. But neither Etruria nor Rome existed in vain. The former contributed to the civilisation of the latter, and Rome in its turn bequeathed to the world its imperishable system of jurisprudence.

Having thus glanced at some rude forms of primitive trade and commerce, as these may be deduced from the practices of wholly uncivilised, or very partially civilised peoples in times more modern, an attempt has been made to refer to the trading and commercial relations of the great nations of antiquity and of times less remote. May it be permitted to allude still further to the existence of the advanced trading and commercial system which the Spanish conquerors of America found existing when they conquered Peru and Mexico, and broke up an old civilization which seems to have had its seat in the then unknown world of the Western Hemisphere.

Prescott describes the condition of the Aztec population of Mexico at the time of the conquest of that country by the

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[1] As to these see *The Cities and Countries of Etruria*, by George Dennis, London, 1848.

Spaniards in the early part of the sixteenth century. Their civilization was that neither of a refined community, nor of a nation of savages. The Aztec, he says, had plainly reached that middle station, as far above the rude races of the New World as it was below the cultivated communities in the Old; and this view is borne out by his description of the mode in which their trade and commerce was conducted. The Aztec week consisted of five days, on the last of which the public fair or market was held.[1] There were no shops in Mexico, but the various manufactures and agricultural products were brought together for sale in the great market-places of the principal cities. The fairs were thronged by a numerous concourse of persons, who came to buy or sell from all the neighbouring country. A particular quarter was allotted to each kind of article. The numerous transactions were conducted without confusion under the inspection of magistrates appointed for the purpose. The traffic was carried on partly by barter, and partly by means of a regulated currency of different values. This consisted of transparent quills of gold dust; of bits of tin cut in the form of a T; and of bags of cacao (cocoa and chocolate), containing a specified number of grains.[2] The occupation peculiarly respected was that of the merchant. . . . He was a sort of itinerant trader, who made his journeys to the remotest borders of Anahuac, and to the countries beyond, carrying with him merchandise of rich stuffs, jewellery, slaves, and other valuable commodities. The slaves were obtained at the great market of Azcaputzalco, about five miles from the capital, where fairs were regularly held for the sale of these unfortunate beings. Slave dealing was an honourable calling among the Aztecs. The merchant performed his journeys with a number of companions of his own rank and a large body of inferior attendants, who were employed to transport the goods. Fifty or sixty pounds were the usual loads for a man. The whole caravan went armed, and so well provided, against sudden hostilities that they could make good their defence, if necessary, till reinforced from home.[3] Describing the city of Tlascala, Prescott says, the population must have been considerable, if, as Cortes asserts, thirty thousand souls were often gathered in the market on a public day. These meetings were a sort of fair, held as usual in all the great towns every fifth day, and attended by the inhabitants of the adjacent country, who brought for sale every description of domestic produce and manufacture with which they were acquainted. It is a further proof of civilised habits that the Spaniards found barbers' shops and baths both of vapour and hot water familiarly used by the inhabitants. The city was divided into four quarters, which might rather be called so many separate towns, since they were built at different times, and separated from each other by high stone walls, defining their respective limits. Over each of these districts ruled one of the four great chiefs of the republic, occupying his own spacious mansion, and surrounded by his own immediate vassals.[1] As regards the *tianguez*, or great market, of Mexico, which excited the astonishment of the Spaniards it is said. There were met together traders from all parts, with the products and manufactures peculiar to their countries; all busily engaged in recommending their respective wares and in chaffering with purchasers. The market place was surrounded by deep porticoes, and the several articles had each its own quarter allotted to it. Here might be seen cotton piled up in bales, or manufactured into dresses and articles of domestic use, as tapestry, curtains, coverlets and the like. The richly stained and nice fabrics reminded Cortes of the silk market of Granada. There was the quarter assigned to the goldsmiths, where the purchaser might find various articles of ornament or use formed of the precious metals. In an adjoining quarter were collected specimens of pottery, coarse and fine, vases of wood, elaborately carved, varnished or gilt, or curious and sometimes graceful forms. There were also hatchets made of copper alloyed with tin, the substitute, and as it proved, not a bad one, for iron. The soldier found here all the implements of his trade; the casques fashioned into the head of some wild animal; the *escaupil* or quilted doublet of cotton, the rich surcoat of feather mail, and weapons of all sorts, copper headed lances and arrows, and the broad *maquahuitl*, the Mexican sword, with its sharp blades of iztli. Here were razors and mirrors of the same hard polished mineral, which served so many of the purposes of steel with the Aztecs. In the square were also to be found booths occupied by barbers, who used these same razors in their vocation. For the Mexicans, contrary to the popular and erroneous notions respecting the aborigines of the New World, had beards, though scanty ones. Other shops or booths were tenanted by apothecaries, well provided with drugs, roots, and different medicinal preparations. In other places again, blank books or maps for the hieroglyphical picture-writing were to be seen, folded together like fans, and made of cotton, skins, or more commonly the fibres of the *agave*, the Aztec papyrus. Under some of the porticoes they saw hides, raw and dressed, and various articles for domestic or personal use made of leather. Animals, both wild and tame, were offered for sale, and near them perhaps a gang of slaves, with collars round their necks, intimating they were likewise on sale. The heavier materials for building, as stone, lime, timber, were considered too bulky to be allowed a place in the square, and were deposited in the adjacent streets on the borders of the canals. It would be tedious to enumerate all the various articles, whether for luxury or daily use, which were collected from all quarters in this vast bazaar. The display of provisions was one of the most attractive features of the *tianguez* in which were also to be found meats of all kinds, domestic poultry, game from the neighbouring mountains, fish from the lakes and streams, fruits in all the delicious abundance of these temperate regions, green vegetables, and the unfailing maize. There was many a viand, too, ready dressed, pastry, bread of the Indian corn, cakes and confectionery. Along with these were to be seen cooling or stimulating beverages, the spicy foaming *chocolatl*, with its delicate aroma of vanilla and the inebriating *pulque*, the fermented juice of the aloe. All these commodities, and every stall and portico, were set out or rather smothered with flowers, showing, on a much greater scale, indeed, a taste similar to that displayed in the markets of modern Mexico.[1]

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[1] Conquest of Mexico (1874), I. 95.

[2] Ibid, I., 122, 123.

[3] Ibid, I., 124.

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[1] Conquest of Mexico (1874), I., 388.

The exchanges were conducted partly by barter, but more usually in the currency of the country. In their dealings it is singular that they should have had no knowledge of scales and weights. The quantity was determined by measure and number. Perfect order reigned throughout the market. Officers patrolled the square in which it was held, and it was their duty to preserve the peace, to collect the duties imposed on the different articles of merchandise, to see that no false measures or fraud of any kind were used, and to bring offenders at once to justice. A court of twelve judges sat in one part, clothed with the ample and summary powers which in despotic countries are often delegated even to petty tribunals.

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[1] Conquest of Mexico (1874), I., pp. 506-509.

The *tianguez* or market place of Mexico was an object of great interest as well as wonder, to the Spaniards. For in it they saw converged into one focus, as it were, all the rays of civilisation scattered throughout the land. It could not fail to impress them with high ideas of the magnitude of the resources, as well as of the commercial activity and social subordination by which the whole community were knit together.[1] Prescott says, that these gatherings resembled the periodical fairs in Europe, as they existed in the Middle Ages, when, from the difficulties of inter-communication, they served as the great central marts for commercial intercourse, exercising a most important and salutary influence on the community.

Herbert Spencer supplements Prescott's statement by observing that, "besides daily markets, Mexico had larger markets every five days, which, in adjacent cities were at different dates, there being meanwhile merchants who went through the whole country buying in one district and selling in others—so foreshadowing a more developed system."[2]

But while the Aztec civilisation seemed to the Spaniards to be hardly inferior to that of Europe, it is to be observed that the Mexicans were not acquainted with the use of iron, and with the art of writing or even of hieroglyphics, and that the absence of roads and the density of forests made communication with the various provinces of the Empire, so difficult as to be almost impossible, and that their commercial relations were conducted mainly by barter.

A glance at the trading conditions of Siberia concludes this sketch. In Siberia the extensive regions of which embrace, it is said, an eighth part of the known world, trade is actively pursued. Sables and the skins of black and grey foxes and beavers long formed the basis of the commerce of the country, which is largely in the hands of the Russian Government. The varieties in the climate of the several districts of the country, occasioning great varieties in the products of each, have led to a widely diffused interchange of commodities between them. The geographical position of the country—bounded as it is by unnavigable seas on the one side, and on the other by unsurmountable barriers—excludes Siberia from direct commercial intercourse with other nations. Its products must therefore pass through Russia, which, however, open up to them the advantages not only of large markets there, but facilities for sharing in the extensive transit-trade of Russia with China. The Siberian trade is chiefly in the hands of natives of Russian extraction, but is also carried on by Tartars and Bokharians, established in the larger cities on the Russian frontiers and in Siberia. The greater number of these merchants, we are told, travel themselves with their goods through the country, visiting in succession all the great fairs, and generally exchanging goods for goods—disposing in one place of what they have obtained in another; and thus turning their capital perhaps ten times during an absence sometimes of several years spent in dangerous and difficult voyages. In many cases, however, the merchants of the various towns and provinces meet in some one of the great commercial marts of the country, there exchange their goods for others which they can dispose of at home, and then return thither direct.

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[1] Conquest of Mexico (1874), I., pp. 510-511.

[2] Tne Principles of Sociology (2nd ed.), I., pp. 531-533.

The chief seat of the inland transit-trade is Irbit, in which place an annual fair is held in spring, which is visited by an immense concourse of Russian and Tartar merchants from all quarters of the Empire. These bring from £5,000,000 to £7,000,000 worth of goods from Russia and Siberia. From the more northern parts of Siberia they present peltry (skins); from the smelting works in the immediate vicinity copper and iron; from Moscow, Archangel, and other places, European goods, principally cotton, woollen and linen tissues, and coffee, sugar, wines, and spices; from Orenburg and Astrakan, the produce of Bukhara, Persia, and India; and from Kiahing, the produce of China. This fair is second in importance only to the Russian fair of Nijni-Novgorod whither the merchants of Siberia also repair.

In the cities of Siberia it is not only customary to concentrate the commercial transactions of the year within the short period of time during which the yearly or half-yearly fairs take place, but the great business of traffic and barter is further limited to an allotted space; it being usual for all the merchants of a city to have their shops and warehouses under one and the same roof.

The great annual fairs here, like those of Europe, have originated in Church festivals, which being held in honour of the patron saints of the localities, caused great concourses of people, and were taken advantage of by traders for the easy and speedy disposal of their goods. In the cities of Siberia, as in those of European Russia, the *gostinoi-door*, as they term what among the Easterns is called a bazaar or caravan-serai, is generally located in the centre of the town, and formed of four wings, enclosing a large square area. On the side facing the street are the shops opening into a covered arcade, which runs along the four sides of the building, and protects the purchasers from rain and sun, while it affords an agreeable lounge for idlers. Opening into the courtyards are the warehouses for storing of such goods as cannot find room in the shops; and perhaps nothing in Siberia makes a more striking impression on the European traveller than to meet in these bazaars, in the regions of snow and ice, in so close contact as to be embraced in one glance of the eye, the natural and industrial produce of all the varied climes of the globe. To all this great commercial activity there are added in Siberia many manufactories and other industrial enterprises, besides a widely diffused system of domestic industries.[1]

In his article on "Siberia," contributed to the Supplementary Volumes of the Encyclopedia Britannica, Prince Kropotkin says, there are no figures from which even an approximate idea can be gained of the value of the internal trade of Siberia; but it is certainly considerable. The great fair at Irbit retains its importance, and there are besides 507 fairs in Tobolsk, 68 in Tomsk, 13 small ones in Yeniseisk, and from 3 to 12 in Transbaikalia, Irkutsk and Yakutsk. The aggregate returns of all these is estimated at 25,000,000 roubles. There are also 71 fairs in Akmolinsk and Semspalatinsk, the returns for which are estimated at 13,500,000 roubles. The trade with the natives, which is a source of considerable income to the local merchants, continues to be mainly dependent on the sale of spirits, and to afford endless instances of abuse. The introduction of railways into Siberia commenced in 1878, and largely extended since 1891, must serve largely to develop the resources of the country, which since 1901 it appears is not to be continued by the Russian Government as a place of exile.

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[1] Chambers' Tracts, "Siberia," x. 15 17. Encyc. Brit. Sup., art. "Siberia."

APPENDIX.

A.

P. 121.—There are illustrations of this among the aborigines of Victoria, among the Samoans, the Andaman Islanders, and the tribes of the Australian Continent.

B.

P. 121.—Various races call every one who is not of their race by terms which signify "barbarian," "savage" or "stranger." So the Hebrews applied the term Goije (Gentile), the Hindoos Mlenchla (mixed or impure breed), the Greeks "Barbaros," the Latins "Barbarus," and the Chinese "Fan Kwei" (foreign devil).

C.

P. 121.—In an interesting book recently written by Mr Hamilton Grierson (Edinburgh, 1903), he refers to the legend of Wayland Smith, who dwelt in the midst of a heap of rude stones at the foot of White Horse Hill in Berkshire, and who, when a piece of money was placed on one of the stones beside a horse which required to be shod, performed that service. The horse being found shod, and the money removed, the smith remaining invisible. This legend he mentions has its counterpart in Lower Saxony and many other countries in various parts of the world, where trade is conducted between parties, one of whom remains invisible. Traffic so conducted is well named, "The Silent Trade," [pp. 41, 47].

He also refers to a slightly different form of this "Silent Trade" in which, as employed by the Carthagenians and other tribes and nations, the parties are not necessarily unseen by one another, pp. 47-50.

In some of the primitive markets held in various parts of the world, customs were observed similar in many respects to those referred to as having existed in the barterings and sales between traders and native races. In some of the Mexican markets, for example, the women exchanged their wares without speaking. In Mecca, in Calicut (a seaport in the Malabar district of Madras), at the market of Basso in Abyssinia and in Tartary, dealers anxious to conceal their bargaining negotiate by joining their right hands under cover, and, by touching the different joints of the fingers, conclude their bargains.

In other places trade was conducted by the two parties occupying opposite sides of rivers or ravines, and negotiating the preliminaries of their bargains from their respective positions. When these proved so far satisfactory, the articles were transferred to a rock in the centre of the stream or place between the negotiators for inspection, in the presence of officers who decided disputes and preserved the peace.

D.

P. 122.—But there are races which seem to have had no notions of barter till intercourse with the white men developed them, and in some cases along with them the spirit of thieving. [King and Fitzroy Narrative of the Surveying Voyages of H.M. ships Adventure and Beagle (1839)]. The Australians at Table Bay when visited by Captain Cook in 1771 had no idea of traffic, and could not be made to understand it. [Hawkesworth's "Account of Voyages in the Southern Hemisphere, London, 1773, III., 634]. Dampier had a similar experience when he visited the North Coast of Australia seventy-two years earlier (1699). When Europeans first visited the Cape the Hottentots were equally ignorant of trading [Le Vaillant, 1780-85, Paris, 1790, II. 120]. The natives near the Straits of Magallan exhibited similar ignorance [Hawkesworth, I. 373].

E.

P. 126.—In his book on the Silent Trade, Mr Grierson mentions that in some cases traffic is carried on through a middleman or woman. Thus Lauder says that on halting at a town on the Lower Niger in order to purchase yams, he was brought to the canoes by the townsmen. They were armed, as were his own men, and had among them an old woman who appeared to be a person of consequence. She directed the yams to be placed in separate bundles, and the owner to retire to a short distance. The purchaser selected a bundle, and placed beside it what he considered to be the equivalent in cloth, flints, etc. The old woman, if she considered the equivalent sufficient, gave it to the owner of the bundle, which was taken by the purchaser. If she thought it insufficient, she allowed the purchaser an opportunity of adding something. If the purchaser did not add anything, she directed the owner to remove his goods, and to leave what had been offered for them. All this was done by means of signs not a word passing between the parties. [Journal of an Expedition to explore the Course and Termination of the Niger, London, 1832, III., 161-63]. Other illustrations of the same practice are mentioned by Mr Grierson, pp. 50-54.

F.

P. 130.—As regards fairs, it may be noticed that the privilege which, in barbarous and semi-barbarous countries, were accorded to those who frequented them, were allowed to a much greater extent to those who attended the great fairs held periodically in civilised countries, in towns, or other central spots most convenient for trade. The right to hold these fairs was usually a privilege derived from the Sovereign, carrying with it important pecuniary advantages to the possessor, and it was his interest, whether he were a great landowner or a town corporation, to hold out important attractions to the travelling merchant and to all others to frequent it. At these fairs, accordingly, the "peace of the fair" was rigorously protected, and extended to those coming to and going from it. In towns the ordinary jurisdiction of the regular magistrates was suspended during the continuance of the fair, and was exercised by the officers of the fair, who were invested with exclusive jurisdiction in regard to all fairs transactions. The regular trading and mercantile transactions of the town were suspended during the continuance of the fair.

The privileges thus extended to fairs and markets in civilised states had their counterpart, and possibly also their origin, in those which peoples in a much ruder condition found it necessary to establish. It may be presumed, therefore, that when markets were held on the borders of contiguous districts, and the site was found to be suitable, and confirmed by usage for a time, it would gradually come to be regarded as neutral ground for all purposes of markets and fairs. Travellers consequently refer to various market sites of this kind being regarded as neutral ground, to which, for all market purposes, traders might resort with safety as regarded their persons and goods. Of such sites in Italy, Dr Cunningham speaks, and Mr Grierson refers to others as existing on the Lower Niger, the Congo, the Prairie du Chien (the Dogs Plain) City, U.S. Wisconsin, Berbera in Somaliland, Mogelo, and the markets of the Kabyles.

Still more would the ground on which markets are held be considered privileged when it was considered sacred. The markets of Greece, held on the boundaries of states, were under the protection of the god's, as the merchants were under the guardianship of Mercury. Possibly the same feeling may have had something to do in times more modern, with the selection of consecrated ground around churches, or of ground associated with the lives and labours of famous saints. Holy places have, in all ages, down even to the present day, attracted the veneration or interest of masses of people, and the gatherings which those feelings secured, afforded every inducement to the trader to make such spots available for business.

In many places away from the haunts of civilisation markets were held to be privileged to this extent that women of different tribes might frequent them with impunity, even when the tribes to which they belonged were at war. In some cases, also, war was suspended during the endurance of the market.

The Treatment of the Criminal and Offender. (A Communication from the Sanitary and Social Economy Section.) By James Devon, Medical Officer H.M. Prison, Glasgow.

[Read before the Society, 24th February, 1904.]

The philanthropist no longer astonishes. We are all more or less anxious to reform our neighbours, physically and mentally; and the guidance offered to the public is amazing, not only from its character but from its amount. Of course when the intelligent reader in the paper which supplies him with his opinions, sees an advertisement telling him that if he has pains in the evening, and a feeling of uneasiness in the morning, he can be put right by Jones' pills, he knows that it is all quackery; but he may buy the pills all the same. The public knows all about quack medicines; distrusts—and purchases them; hence we have so many; but even those who, in medicine, detest and abjure all quack nostrums, in social subjects fall easy victims to them. What after all is the essence of quackery, but the assumption that diseases are entities, and that what has overcome them in one man will do so in all? By metaphor, we talk of diseases in the Commonwealth, and before we know it we are discussing, say, drunkenness and crime as if they existed apart from the individuals who indulge in them; and assuming that what cures one will cure all. When in practice our theory is discredited, we talk of classification of cases, and set about to multiply institutions and officials. But they are not cases with which we have to deal; they are human beings differing widely from each other; and if they are to be helped to free themselves from their vices, that is the first point to be recognised and the main point to be borne in mind. "The only way to make a man is—think him one." If we could do that, we should probably be less anxious to make him conform precisely to all the details of life as we would have him live it. Perhaps in time we should get rid of the superstition that institutions are necessarily good things, and be less ready to send prancing over the country, intelligent, zealous officials whose mission seems to be—to shut up every one who is a different kind of fool from themselves. Of course I do not suggest that all "institutions" are useless and harmful; some are not so bad as others; but I think we could do without shutting up so many people who do not act just as we desire, if we would only be a little more reasonable than they are. I hope therefore that there will be no disappointment when I say that I have no specific to present to you for the treatment of the criminal; but only some criticisms and suggestions which are certainly not new, and which will not be universally admitted to be true.

The treatment of the criminal and offender has varied in all countries and at different times. Here, the tendency has been towards leniency and away from the retaliatory principle. Prisons are no longer the dark, dirty, disease-producing places they once were. Prisoners are lodged in separate rooms; and their association without supervision is in most cases prohibited. Their detention is not accompanied by bad treatment; but as a rule it does not result in their improvement. Whether it is meant to do so, it is hard to say; for our criminal law seems rather to be based on the retaliatory principle than on any other, and we hear much more of punishment than of reformation. Probably it is meant to make the culprit suffer for his wrongdoing, in the hope that he will do right in the future lest he should again come under punishment. Unfortunately he is led to believe that the mere submission to punishment purges him of his fault; but the only possible expiation of past wrongdoing is future welldoing, and the practice of regarding a legal penalty as payment to society in discharge for the wrong done is essentially vicious.

In Scotland the record of a criminal on trial is kept from the jury. His past conduct is not allowed to bias their opinion as to his present guilt. The question is—has this man committed this crime? That settled, the question becomes—what are you going to do with the man? The judge may only exercise his discretion within certain limits. The sentence he must pass in certain cases is absolutely laid down; and in other cases he may be obliged to inflict a sentence which in his own opinion is either too little, too great, or otherwise not suitable under all the circumstances of the case. The prisoner's past convictions for similar offences, and the sentences passed on him for them, are brought before the judge. This the prisoner considers unfair; and he is not without sympathisers. If there be a tariff of penaltities for offences, which he may pay by undergoing sentence, he is no doubt right: he should not have to pay twice.

Broadly speaking, all a judge can do is to order the culprit to be kept off the streets for a longer or shorter period. The public is guaranteed against annoyance from him for the time determined; that is all.

As a place of detention the prison is, in the main, quite admirably arranged; but a very large proportion of its inmates find their way back, not because they like the place: they much prefer to be outside the walls: but because their prison experience has failed to produce either a deterrent or a reformatory effect on them. True, now and then the newspapers report that some one has asked to be sent there; and expressed a preference for prison rather than the poorhouse. Then we have protests made against the pampering of prisoners. But these preferences are only expressed by prisoners who are in custody, and about to be sent somewhere under bonds. There are few indeed who do not prefer freedom and discomfort, to prison and all its pampering. They return there against their will because they have again transgressed: and the more they come the less likely are they to cease coming. Their vicious habits are latent there, and are warmed into activity by their life on liberation. They do not like the prison more, but the poorhouse less; and I am much of their way of thinking, for if they have less liberty they are at any rate better fed and better lodged.

One often hears it said that prisons could be made more deterrent; the assumption underlying the statement is, that the more severe you make punishment the less likelihood there is of the offence being repeated: this is not borne out by experience. With milder methods of repression we have not more, but less, crime: and certainly much less brutality. There are some who would drive out crime with the lash; one usually finds that they are very kindly people who spare the rod in their own homes; if they had to attend the administration of their prescription they would probably alter their opinion. There is no argument for the infliction of the lash that would not equally apply to the use of the rack and thumbscrew. Indeed, with modern machinery these might be so finely graded that they could be made to inflict far greater torture than the lash, without making it necessary to put the culprit in hospital afterwards and dress his wounds. Electricity too, offers endless possibilities; and as it cures so many things, it might not only torture but reform the criminal. Its application would certainly not have such a sickening and brutalising effect on the operator and spectators ; and, after all, not only has the effect of a punishment on the subject to be considered, but also its effect on the person administering it. For my part, I do not think that past experience of the lash encourages the idea that its revival would deter from crime. In the case of juvenile offenders, however, whipping is certainly better treatment for them than sending them to prison, but it is a bad best.

The great majority of prisoners come direct from police courts. The routine which they undergo may be shortly sketched, so as to afford an idea of our present method of dealing with prisoners and offenders (not convicts), from the time of their arrest till, and after, their liberation. The prisoner, after passing the bar of the police office, is put in a cell and detained there till the morning. If there be not sufficient accommodation, others are placed in the cell with him ; but an effort is made not to put unknown prisoners with old offenders. Still, it is bad practice to shut up strangers together who are charged with offences ; for the close intimacy into which they are thrown—all the closer because they are comrades in misfortune—offers opportunity, and may provide occasion, for the formation of companionship in ill-doing outside. Although till tried he is presumed to be innocent the prisoner in the police cell is in all respects worse off than he would be in prison. Of course, if drunk, he is not likely to be conscious of his discomfort; but if sober he is not at all likely to enjoy his bed—or rather the want of it. At court time he is brought forth for trial. I understand that such as ask for it may have water with which to wash themselves, but, judging by their appearance on their admission to prison, not many ask. In court his unwashed and unkempt appearance is not likely to predispose the Judge in his favour. The Magistrate is a busy man. He has usually no legal training, a strong sense of the pity of it all, and not very much time ; and so the culprit gets what justice the gods send—sometimes as one of a batch.

If remanded he is taken back to his cell. There is no such diet provided for him as for the convicted prisoner. Bread and water is his staple food, unless he or his friends can provide better fare. Or he may be sent to the Sheriff ; even then he is not compelled to make himself clean and presentable. Certainly if prisoners from prison appeared in court as they do from the police cells, there would be complaints, and rightly; for it does not conduce to the advantage of the public nor of the officials, that into a busy court dirt should be officially brought. If convicted, he is in due time removed to prison in a badly-lighted, ill-ventilated van, in the company of others, many of whom are probably well acquainted with the journey, and quite pleased to compare notes with him and arrange to complete his education.

Arrived in the prison, he is put in a separate box, and in his turn asked for certain particulars regarding himself. His possessions are inventoried, disinfected, and put past. He is seen by the M.O. and sent to the bath, after which he clothes himself in prison garb, and is passed on to the cell allotted to him. He is instructed in the rules to which he must conform. His cell is clean and he has to keep it so. The bed, unless for females, juveniles, or aged persons, is of board. His blankets and clothing are fresh and clean, and his diet is sufficient and of good quality, if monotonous. He has three meals a day; and is allowed an hour's exercise, which consists of walking round a space in single file with others, to whom he is not allowed to speak. The rest of the day till bedtime is taken up with work, and visits from the chaplain and others, who exhort him and try to influence him for good. The routine day is thus one divided into periods of work, prayer, refreshment, and sleep.

There is often difficulty in getting work for prisoners: they must not compete with workers outside, who apparently prefer to keep them rather than allow them to contribute by their labour to their own upkeep. They are principally employed at occupations at which they could not earn a living outside. This may teach them the dignity of labour and the blessedness of work: but I doubt it. However, under present conditions it is the best that can be done. Many are not in prison because they have been idle or because they have not been able to earn a living, but because they have not been able to spend their earnings wisely. These do not need to be taught to work, but to take to recreations not harmful to themselves and the community. Most of them do not attend religious services except when they are in prison; but some make an ingenious distinction between religion and conduct. I remember one old woman who had grown grey and almost blind in criminal life. She was eloquent regarding a person whom she described as "Nae better than an infidel." I mildly remarked that at least he had kept out of prison; to which she replied "Ay, but though I hae been a drinker, a blackguard, and a thief, thank God I never neglected my releegion." I have before remarked that people in prison do not essentially differ from many outside. It is not that they are ignorant of the teachings of religion; but that they are regardless when at liberty.

There is no want of earnestness and zeal on the part of the many who visit and exhort them, but there is a fatal difference of standpoint. The ideal held up seems impossible of attainment, and I am afraid in many cases there is no strong desire to seek it. Something is done in the way of helping prisoners on liberation, by trying to find work for them, and by gifts of money or clothing. But it is not always easy to get into work even after a few days in prison. Curious as it may appear, it is far more easy for a man to get drink than to get food or work. It is the recognised way of treating; and if he meet an old acquaintance drinks are set up, and the money that might have gone to help, goes to hinder him: all with the kindest intentions. I have known a case where a man liberated from prison after a short term with no money, met his former workmates, shared drink with them, and primed with it, committed a murder for which he was afterwards hanged. This was an extreme case, but it was not the first time under similar circumstances that, like others, he had committed assaults. The treats are kindly meant but mistaken.

Attempts are made to overlook and influence such of the women as have no friends, by placing them in "homes." No doubt some good is done by these means, but there is very grave danger of considerable evil being done also, through the association of girls who have just entered a life of vice with those who are experts. It is an ungracious act to criticise the work of those who alone are attempting to do anything whatever to rescue from misery the outcasts of society. Their good intentions are apparent to all who come in contact with them, and their zeal and persistence are marvellous; but one cannot shut one's eyes to the fact that much of the mischief done in the world is the result of well intentioned, zealous, and badly informed effort. Thus the downward slope is paved with good intentions.

The idea of placing girls in homes is excellent; but they are not placed in homes. You cannot transform a house into a home by changing its name; and there is a wide difference between family and institution life. They are not all alike, but in many of those places the girls sleep in dormitories containing a dozen or more beds. Conversation, after work is past and before the inmates sleep, cannot be prevented; and matters of common interest become the subject of discourse. One compares experiences with the other; and what a girl does not know of vicious life when she enters, she is likely soon to learn. Such a home is the last place which I would think of recommending to a girl young in crime: as for the old hands, one put her view very clearly to me when she said—"Would *you* like to work ten hours a day and after some months of a life of working, eating, sleeping and praying, get nothing for your work, but maybe a change of clothes and a job at a low pay?"

In such homes the inmates have no reason to complain of their food nor of their lodgings, but many have reason to complain that they are not adequately paid for their work. When a girl loses her reputation she finds difficulty in getting a situation; people who pay well quite naturally prefer steady workers. The only situations open to her, therefore, are those which are worst paid; from these she may by redeeming her character obtain more remunerative work elsewhere. She recognises that a bad reputation lowers the market value of a female worker—that is, she has to do more work for less money. What she does not so readily admit is that it is just. She thinks that if an individual take advantage of her necessity and underpay her that is one thing; for a Christian Institution to keep her working for insufficient pay is quite another thing, and there is a good deal to be said for this view. A girl in a "home" is little better off than she would be in a prison. She has harder work, almost as little liberty, more varied diet, and for associates, others like herself. Unless she stay for an extended period she gets no wages. The life bears no resemblance to healthy family life. Girls go there because they can do no better, and it says a good deal for the intensity of their desire to do well that some of them stay for months. One quite recognises that to the majority of these institutions it cannot be charged that they make money by the girls. They are often carried on at a loss, for the oncost is seldom small. But reformatory work cannot be conducted on a commercial basis. It is in the nature of things that it should not pay its way in the narrow sense: the cost of adequate supervision prevents it; and to charge the cost of their reformation to the girls is to inflict at least an apparent injustice on them that is apt to rankle in their minds, and to drive away a number who would otherwise be helped—

helped at a pecuniary loss to the home but to the great benefit of the community.

Their charity should not have the appearance of that of a decent woman who rather prided herself on her goodness. Her husband had a small business, and the first-year apprentices were occasionally requisitioned by her for assistance at cleaning time. On such an afternoon a newsboy coming to the door, she got a *Citizen* from him, gave him a penny and received back the halfpenny of change. When he had gone she remarked to one of the apprentices—a boy with a genius for saying the right thing in the wrong place—"Puir boy, I just take the paper from him for charity." To which he replied, "Aye, but ye took the halfpenny back!" There was something to be said for both views; but he had the last word and he soon found that his criticism had borne fruit; he was dismissed.

The routine treatment to which the convict is subjected is much more severe than that which is applied to the ordinary prisoner, and it does as little good. It is a system of repression mainly; a sitting on the safety valve that is apt to provoke outbursts of temper and violence resulting in assault. These may be punished with the lash. A power which is not possessed by the judges of the High Court is granted to the prison Commissioners. It is considered necessary in order to maintain the system; but as no one claims that the system is in any degree reformatory, it is a little difficult to understand why it should be maintained. The same man who is at one time a convicted prisoner in an ordinary prison, at another time may be undergoing penal servitude. While he is in an ordinary prison there is neither power nor occasion to order him the severe punishments which may be inflicted on convicts; there is more need to humour him to some extent. If he need the lash when he is sent to penal servitude, there is at least a presumption that the cause lies as much in the character of the life he is compelled to lead, as in the character of the man. The more punishments inflicted on prisoners in a prison, the stronger the probability is that the place is badly managed. Repression is necessary, no doubt, but repressive powers should only co-exist with power to reward. Even a donkey will go further after a carrot than when driven by a stick. It never does any good to a man to treat him as a machine, and the tendency to do so under the name of discipline is the root vice of the whole system.

Stated shortly and broadly, the treatment of criminals and offenders in Scotland consists (*a*) in trying to make the punishment fit the crime by a term of sentence more or less fitted to the offence; (*b*) placing prisoners under conditions not comparable with any thing in civil life outside; and while seeing that they are sufficiently housed, clothed and fed, doing practically nothing to make it easier for them to live decent lives on their discharge; (*c*) giving them advice, money and goods on liberation in a more or less haphazard manner; and in the case of women placing some of them in an Institution for a time; (*d*) by personal interest and attention attempting to restore one here and there to well-doing in the social rank from which he has come. I suggest that better results could be obtained by (1) keeping as many out of prison and institutions as possible, by (*a*) an extension of the system of inflicting fines, (*b*) appointing guardians over culprits, who would undertake their supervision, (*c*) boarding out where the character of the culprit would permit of that being done; (2) transforming prisons from places of detention merely, into reformatories, (*a*) by approximating the conditions of life within to that of family life outside, (*b*) by the education of the criminal.

An examination of the Reports of the Prison Commissioners for Scotland, will suggest to anyone that a good deal might be done to diminish the number of committals to prison. In 1902 there were about 63,000 receptions of persons under sentence of imprisonment.

The Commissioners estimate that as some persons were in more than once during the year the number of individuals represented is probably about 46,000; and of these about 16,600 were in for the first time. Their sentences ranged from under one day to two years. There were 59,000 sentences of a month or less, and of these 34,000 were of seven days or less; 9,800 were of three days or less. These people have not much more than time to get accustomed to their quarters before they are liberated; and if there were the means, there is neither the time nor the opportunity to make any thorough enquiry into their dispositions and way of living, with a view to help them. As for the offences, there were 22,500 committals for breach of peace; 17,800 for drunkenness; 5,900 for obscenity. Practically all these are offences inferring drunkenness. Where did they get the drink? It could not have been in the public-houses, for from the tables it appears that only one person was sent to prison for breach of certificate. If the source of supply could be discovered and cut off, or at any rate made to flow less freely, it seems obvious that there would be a much smaller prison population. But is there any good purpose served by sending people to prison for a few days? The streets are rid of them, but such as are habituals go out simply revived by the rest, and keen as ever for drink. I say the habituals, for time and again these return with sentences of 2, 3, 5, or 7 days. As for the casual it would be far better to let him off if he cannot pay a fine, than to send him to prison. That can only cause him to lose his employment and bring him into bad company. It is making bad worse. No doubt he deserves to be punished—so do we for permitting him to get drunk. Fortunately few of us get all we deserve. This class of offences forms the great majority of our committals; for drunkenness is an element in many more offences than those falling under the three heads which together gave us more than two-thirds of our receptions in 1902.

If a man do not get drink to excess he will not get drunk. Persons and premises are said to be licensed for the convenience of the public; and it is not for the public convenience that a practically unlimited supply of liquor should be had. No respectable publican wants to make men drunk; but he wants to make money at his business, and beyond certain limits he cannot be more particular than his neighbours. It is sometimes very difficult to say when a man is drunk, but it is not difficult to tell when he is not sober! I do not think he is entitled to the benefit of any doubt that may exist. After all it is surely the business of the vendor to know when a man has had enough. He may make mistakes, but they will be on the right side if he has to pay for them. It is not a little curious to note that if a man who has had some liquor commit a serious assault, efforts are made to extenuate his offence on the ground that he did not know what he was doing because he was not sober. If the same man in the same condition ask for a drink, it is assumed that he knows quite well what he is doing; and even if his companions say "You've had enough already" he will get it. Of course a man may get drunk in a private house: making it more difficult to drink outside would not stop that: but, even so, it would tend to keep the streets free from disorder; and if a man must make a beast of himself it is alike better for his own health and the public convenience that he should do it in private.

Those who are incapable of taking care of themselves, or disorderly in their conduct through drink, and are taken into custody by the police, if not known as habitual offenders, might quite well and profitably be let out when sober on a nominal pledge. The disgrace will appeal as effectively to any person with a sense of shame as if he were brought before a magistrate and made a public show of in the company of the hardened. If, however, a fine be inflicted, time for payment should be allowed. A man will never earn money to pay the costs of his prosecution, in prison ; but if allowed to go about his business he may do so ; and if he earn his keep and behave himself for a term outside prison, he has done more than it would have been possible for him to do inside.

Of other sentences 2,382 were for loitering and importuning passengers for the purpose of prostitution. Most of them were from Glasgow courts. All who know Glasgow will acknowledge that there is remarkably little annoyance caused to men by women of the streets. That there is an enormous number of prostitutes in the city is equally well known, and the immense majority of these never reach prison. Any one considering the facts (1) that the personnel of this army changes frequently, and (2) that in the public institutions of Glasgow no very considerable number of them die, is driven to the conclusion that, left alone by officials, the most of these women drift out of their vicious way of living just as they have drifted into it. Prostitution is a temporary phase in their life ; not a permanent condition. Those who are mastered by the craving for drink do not readily recover; and those who are sent to prison have their chances diminished thereby. These latter are only the poorest; such as can pay a fine and those who have money enough to live in a house of their own, and sense enough to prevent disorderly conduct there, cannot be sent to prison.

There is no doubt that if there were not men seeking them, these women would not be there; but the streets should be kept free from scenes of disorder, public decency safe-guarded, and the citizens protected from molestation. For the attainment of these objects all means are not justifiable; and they could quite well be accomplished without the oppression of anybody. The mere presence of the abandoned woman in the streets, is an offence to some people; but even though she may have gone astray, she might in fairness be allowed to walk abroad. She may be seeking whom she may devour: but on the other hand she may not. If not behaving like a roaring lion, but passing along quietly and without disturbing anyone it is not necessary to enquire why she is doing so. She does not desire to attract attention from policemen, and if a sufficient number of men in uniform are patrolling the street she will keep out of the way. Even if a woman care little for the observation of the public when she is in conversation with a man, he is usually not desirous of attracting attention. He wishes to preserve his reputation, and if he were seen speaking to a suspicious looking character people might say things: the world is so censorious.

Streets well lit and well patrolled will tend to prevent the making of assignations in public, and the annoyance of passengers. But the zeal of the authorities carries them further. Young men, policemen in plain clothes, are sent out to spy upon women and seize such of them as are seen to speak to men, always provided that the woman is sufficiently weak and defenceless. A good reputation and decent friends to speak to it saves a woman from prosecution; but the woman who has gone astray—against whom there is a prejudice which makes it more difficult for her to do well, and who by reason of this inability to protect herself should be the more carefully protected by the law from the tyranny of those who are always ready to prey upon the weak—this is the woman whom it is sought to entrap. The practice is in the highest degree unworthy; for it is not an attempt on the part of the authorities to prevent wrong doing, but, in effect, to seize these women and exact a moiety of their earnings in the name of fine, or send them to prison in default.

The girls themselves say that they are blackmailed by some of the men sent out, and certainly the system offers excellent opportunities for such an evil practice. The girls' statements are consistently disregarded, for are they not women of no reputation? But such statements are made by so many, that I for one do not think they should be summarily set aside. To accept them as true would be to libel the whole Police Force, it may be said; but I cannot admit that. Let it be granted that there are no bad men in the Force; some of them are not so good as others; and even a policeman is not out of the reach of temptation. You take young men, not highly paid and not necessarily having very high ideals, and send them out for the purpose—not of warning bad characters off the streets, but of lying in wait for, and seizing them if they are seen to speak to any man. The girls are anxious not to go prison, and when arrested they do their best to induce their captors to let them go. It is not wonderful if in some cases they succeed. With all his good qualities the policeman is not exactly suited for the part of Haroun-al-Raschid. If a man is induced to take a bribe—a present—a thank-offering, he will soon get into the way of looking for it; and the girl who pays best will have the best chance of evading arrest. But someone must be arrested; that is the purpose for which the men are sent out. If all were arrested the cells would not hold them: accordingly time after time there is the same procession of the poorest and most pitiable of the frail sisterhood taken into custody. They are duly brought before the magistrate. The two men who have arrested her, swear that at the time and place charged they saw the prisoner, whom they know to be a prostitute, accost two—or three—men whom they do not know. They did not hear what she said. She denies the charge, but then it is to her interest to do so! On evidence such as this she is convicted and sentenced for importuning. Thus "importuning" on the part of a prostitute would appear to consist of being seen to speak to men in passing—words which apparently cause so little annoyance that the men make no complaint. It is a new, eccentric, and almost incredible interpretation of the meaning of the word. Many of the convictions are bad in law, and the proceedings are a travesty of justice. If men were treated in this way there would be a fine outcry, but these women have no friends; no one cares to charge himself with the righting of their wrongs; though surely it is possible to detest vice without treating the vicious unjustly.

I have tried to state the facts from the standpoint of the women. It is no answer to say they have an interest in distorting the truth; for equally so have the men. Without doubt the system is liable to very grave abuse. The official branding and hunting of a girl hinders her chances of reform and confirms her in her vicious courses. The system should be abolished. No fair minded man would defend it, nor would the public conscience approve it. It is oppressive to the woman, and is an unhealthy occupation for the men; for it is not wise to subject them to the temptations to abuse of power which it offers. Public decency need not be diminished in the least degree; and a little less attention to the women might be more than compensated by a little more attention to the men. There is far more reason for women to complain of insults offered to them by men, than for men to complain of annoyance by women. As it is, a comparatively small number of these women are made the scapegoats and sacrifices for the others, and for the vicious of the other sex; the woman pays.

It is a shameful thing that we should use the resources of this great city to support a system of espionage, and potentially of blackmail, on a number of miserable creatures—a system we dare not apply to men.

Any exhaustive and impartial enquiry into prostitution in Glasgow would be a foretaste of the day of judgment, and would result in far more harm than good being done—as usually happens when men's vices and follies are publicly exposed. We may at least remove obvious causes of reproach, and not seek to sink the fallen woman deeper in the mire.

Thanks to the provisions of the First Offenders' Act, many culprits who would otherwise have been sent to prison, have been released on probation, appearing at Court some months afterwards and receiving their discharge. They go back to their occupations and in very many instances are never heard of again. Of them "no news is the best news." An extension of the practice is desirable. There are other cases where fines are now inflicted as an alternative to imprisonment, and paid; and the principle of allowing a fine and time in which to pay it should be further extended. It is pitiful to see anyone appearing in prison for the first time, when one knows that at the expiry of his sentence the chances are all against his doing well. One can but dimly imagine his feelings on liberation, after some months detention during which he has been shut off from the knowledge of events which have been happening outside. His conviction, after being nine days' wonder, has been forgotten. His acquaintances have been affected by all that has been said against him, and imprisonment has caused his good qualities to be obscured. His family have probably suffered more than he from his absence, and he himself is at first dazed by the turmoil of the streets. Even when a man has been laid on a sick bed for weeks, he finds it difficult to catch up with events when he is able to go about. He is more or less bewildered if left to himself. Add to this the mixture of shame and bravado with which the discharged prisoner faces the world; and the anxiety he has in order to obtain a living, if he is bent on doing well. If he be able to overcome his difficulties it is often due to his good luck or his good friends; and it is no matter for surprise if he recklessly consort with others who, desperate like himself, seek a living by crime. No one is a bit the better for it all; and the community is a great deal the worse.

There is the deterrent-effect-upon-others theory which is certainly old enough now to command respect. But the deterrent is not his sufferings: the "others" do not see them. They did in the days when a man was hanged—not for stealing a watch, but in order that watches might not be stolen; yet crime was not diminished thereby. An honest man is not honest because he might be caught; and the dishonest man fancies he is too sharp to be caught. The problem is to make the culprit feel he has done wrong, without at the same time, making it easier for him to do wrong than right in the future. It is not solved by imprisonment; and there is this to be said for the infliction of fines that the culprit feels the effect in that very sensitive part—his pocket.

In cases of breach of trust and such offences generally, the effort might be made to procure restitution to the injured party as far as possible, and that with a fine to the State. If the culprit's friends had to raise the money for him, they might be depended on to take it out of him in some way and to look better after him in the future; for many of the young men belonging to respectable families, who go wrong, do so because they are not properly looked after. Those who could not pay might be liberated on the security of reputable persons who would undertake to supervise their behaviour for a period to be determined by the Court—that is all that is at present done by imprisonment. This would not make the punishment fit the *crime* but the *criminal*. A fine of £10 is to one man nothing: to another more than he can earn in two months; and it is surely less absurd to consider the effect of the sentence on the man than to disregard it.

In the case of some offenders against the person the same principle might be applied—compensation to the injured, where required, and fine to the community. These offences are largely associated with drunkenness; and anything that diminishes that curse will diminish them. No adequate compensation can be made for a serious assault; but it does not improve matters in the least to do anything to the culprit that would tend to make him worse.

In serious offences against property and against the person, and in such as show ingrained perversity and malignancy, the culprit would necessarily require for his own benefit as well as for the public safety to be put in bond for a lengthened period; just as would an habitual offender. The point on which I would insist is that many of the acts for which people are sent to prison are isolated, or at any rate not at all common, events in their lives. If it be to the interest of the person and his friends to prevent their recurrence they will try to do so ; and imprisonment is not likely to increase their interest in or influence on the offender. If we were as anxious to reward men for the good, as to imprison them for the evil they do, a good many of the prisoners we get (living as as they do under conditions that make wrong-doing easy), would have a balance to their credit that would put some of us to shame.

A large number of people are neither very bad nor very good, and go astray because they are easily influenced by those around them, and find encouragement to indulge too largely in the pleasures of the senses. They are not very difficult to manage, and readily and without murmuring submit to conditions imposed on them ; but they seem unable once they get into bad company to break away from it. There are many not at all useless persons among offenders, of whom it can be said as the result of experience, that they are not fitted to cope with the temptations of city life. It is the practice to board out in the country certain persons of unsound mind. The practice might be extended to include some persons convicted of crime, *e.g.*, (1) those whose friends are not satisfactory guardians or sureties in respect to their age, general character, or social condition; (2) those who could not reasonably be expected to carry out the conditions of parole in town; (3) and those who by their progress and conduct while in bonds, had given reason to believe they could be trusted on parole. Naturally one looks to the churches for help in obtaining suitable guardians. In the country the heads of the churches may be expected to know the character of the people there, many of whom for a consideration would not only be able but willing to look after a person who had gone astray, and to encourage him to live decently. The unfortunate thing is that both in the churches and out of them, there is too much of a tendency to leave everything to a committee—the easiest way of shirking the duty of personal service; and machinery which by subdividing labour was originally intended to enable more work to be done, merely grinds the wind and becomes a means whereby all work is shirked.

When the churches have revived the old doctrine of the duty of personal service, and their members awake to the necessity of doing something more than "patronising" schemes for the rescue of the submerged, many proposals which are now considered quite impracticable will be carried out. We have societies innumerable. Everybody who is anybody is an office-bearer of one or of many; yet still their members grow, and still the results are disappointing. Money can never take the place of service. It is far easier to give a man money than to teach him how to help himself—and far less profitable. Accordingly there are people who live comfortably although parasitically, by an affectation of piety judiciously blended with humility and flattery; in one sense they have found that godliness is profitable. Others trade boldly on their infirmities. The fisherman covets the big fish; and the old hand knows this, nibbles a good deal, and is not often hooked. Much more is given by societies to confirmed offenders than to those who appear for the first time. These latter do not know their way about and are ashamed of their position. A few imprisonments help their instruction in this direction.

The most hopeless persons are the aged and infirm. Some of them have only become submerged late in life and are quite unable to extricate themselves. They pass from prison to poorhouse and back, with short intervals in lodging houses, and on the streets, where their misery is a living reproach. They do not interest; they merely disgust the charitable passenger. It has been proposed to shut them up in the poorhouse because they go in and out too frequently. That practically means starting a prison in the poorhouse. Perhaps it is prison enough already; but if we can do nothing more for our unfortunate poor, who are no longer able to maintain a home of their own, than shut them up in huge barracks where privacy is impossible, we need not add insult to injury by placing a prison in their midst. If these miserables must be shut up, the prison is the better place for them; but surely they might be placed in the country, and during the few remaining years of their pilgrimage get fresh air and some space to move about in. Their feebleness makes their custody less difficult, and renders it possible to lengthen their chain. All this of course is to treat them better than we treat "the deserving poor" as they are called, who having outlived their friends and their powers, have ceased after a laborious life to be able to maintain themselves. But we treat nobody worse than these poor. Their complaints are too feeble to be heard. If they would only rebel or become insane they would become a "problem" or be made more comfortable. At present to plead for anything more than a new barracks for them would be premature. The most clamant are first attended to. The insane have had their turn and we are now engaged with the criminal and offender—the rebels. When the "wolves" and "wild beasts" have been dealt with—and found to be men and women potentially useful—the sheep may be attended to.

I have attempted to show that it is possible to avoid sending many to prison, by allowing them to work out their own salvation assisted by their friends and guardians: and there is at least room to hope they would be successful. If it be granted that crime is no more an entity than is disease, it is difficult to resist the conclusion that it is the person who requires treatment in respect of his act, or rather of the condition he has got into, and from which the act has resulted. If this be the case, then the proper punishment for the commission of crime will be such as will be most likely to bring the criminal to a better course of conduct, or will at least tend to make him live as a member of the community without outraging its laws and customs. If so, the punishment ought to "vary as the individual" rather than "vary as the crime." This implies a study of the causes of crime, such as if carried out might throw a great deal of light on many other social problems. Into that matter it is impossible now to enter. This is clear that whatever you do with your convicted prisoner, unless you keep him perpetually shut up, or kill him, he will sometime return among you for better or for worse. He will have to obtain a living whether honestly or otherwise; and in any case he will have to accommodate himself to some extent to the conditions of life which obtain among those around him. It does not seem wise, therefore, to take a man away from his social circle, and from the censure and support of those to whose special interest it is that he should do well, and place him under conditions which resemble nothing in ordinary civil life. If he have no friends and associates but such as are regardless of law, or if he habitually disregard their efforts to influence him for good, then it becomes necessary to remove him for a time from society. But this is not sufficient; he should be placed under conditions as near as possible in their arrangement to those of the better disposed and free members of the community, and there treated for his vices and evil propensities.

The habitual offender and such others as by their acts have made it unsafe for the community to allow them liberty under guardianship might be sent to prisons—but prisons quite differently constituted from those presently existing. Their sentences would require to be long sentences, but capable of being reduced by the judicial authorities on satisfactory evidence that they had improved so far as to be likely to earn their living outside without undue risk to others.

Perhaps some day we shall all live in phalansteries, but meanwhile people live in family groups; and barrack life, under whatever name called, is neither popular nor general. Whatever we think, even the most independent or eccentric of us has to conform to a very large extent to the way of his neighbours, and that is a very important one of their ways.

There are bad homes as well as good ones, but it is a very bad home that is not better than none. The institution, however well managed, is never like a home. There is not the privacy, nor the degree of equality, nor the tolerance of individual idiosyncrasy, nor the intimacy between its inmates; and the larger it is the less is it like home. The very extent to which the division of labour that lessens work can be carried, mark it off from the ordinary household. I do not suggest that this organisation of inmates is a bad thing, but it is a different thing, and if the object of the institution be to train its inmates for life outside, in so far as its arrangements and constitution differ fundamentally from those in ordinary households, it will tend to that extent to unfit them to accommodate themselves readily to these conditions. It is important to teach a man to work, but his work should only be a part of his life, and it is much more important to teach him to live.

Many criminals are neither lazy nor bad workmen; they have worked well and lived ill. While they are detained in prison they should be kept as nearly as possible under conditions such as they might easily find outside. The practice of giving each a cell—a room—is admirable. It ensures him privacy and may teach him to value it, but not if he is compelled always to stay there. The aim should be to develop his powers, to teach him to apply them in useful directions, and to do so under conditions approximating as nearly as possible to those which obtain in any respectable household of the class to which he belongs, so that on his liberation he would not have a difficulty in adjusting himself to his surroundings when he went back to the station in life for which he had been fitted. The method by which to attain this aim I cannot prescribe. Obviously it would vary with different persons, and the variation would depend as much on the teacher as on the pupil. To lay down minute rules for all classes, and enforce them by penalties, would simply be folly. First of all the man must be taught to think for himself; and this is not so difficult as might be supposed. It might be difficult to teach him to think as you want him to, but that is a different matter altogether. Most people, in prison or out, are not unreasonable; that is why they do not agree. The trouble is that they too often think it unnecessary to reason, perhaps because they have found that they can get on better without. What a world it would be if we all did only what was purely rational! If the man be taught to think for himself there is a chance that he will learn to tell the truth to himself; and that practice is the best moral antiseptic, for the man who gets into the habit of lying to himself is in a bad way indeed. He should be taught to take an interest in his room and a pride in his possessions, and if he worked well and showed signs of improvement he might be allowed to have opportunities of making it more homelike and less bare. His ideas of adornment might be extensive and peculiar, but you will far more readily reason or laugh a man out of his bad taste than bounce him out of it. No two are exactly alike, and no two could be treated exactly alike. He should, therefore, if possible, be gently led out of his past and stimulated to the formation of better habits, rather than dragooned till he is disgusted and resentful. Everything cannot be done by moral suasion, but not much can be done without it.

The general method to attain the reformation of the Criminal would be to find out his powers and educate them, and to teach him how to get the best out of life without injury to himself and others. He needs not only training in work whereby he may earn a living, but also in wise recreation; there are those who think that nothing in life or letters can be serious which is not dull. The woman should be treated with the same object, and on the same principles. If one half the ingenuity spent in leading some of them astray, and in oppressing them, were devoted to their reclamation, the results would amaze. Any method of treatment could not be carried out in detail by a centralized authority. No educational policy can be; though the cramming of people with information—which in after life they are glad to be rid of—can be too successfully superintended, provided there is a man with a theory at the head of affairs. The successful teacher is the man who can draw out his pupils' powers, not the man who can cram and so injure his mind, and he will be the less successful if curbed by petty restrictions. What is required is not a bureaucratic system with men of the automatic self-registering machine type so dear to the official mind as agents, but the provision of men who will try to understand and help men.

When sufficient progress had been made, steps might be taken to have him liberated under guardianship. If he did not do well he could be brought back, but he should not be required to report himself to the police as at present. It is not necessary to believe all the tales of ticket-of-leave men as to "police oppression": most of the oppression is wholly imaginary, but the imagination has an important influence on conduct; and, if a man believe that he is being hunted down, it is bound to distract him from the effort to do well. Those liberated on license could be visited at intervals and without notice by someone appointed for the purpose—the local minister, or the governor, or other superior officer acquainted with him in the place of his detention. He should be supervised in a friendly way and unobtrusively, rather than with suspicion.

If it were only a new kind of building that were required it could perhaps be had. We spend millions on stone and lime palaces for the insane, and the present wave of interest in the criminal and outcast might result in the building of new model prisons, and of "homes" for habitual offenders; but it is not machinery but men that are needed, and there is little likelihood of their being sought out and put to work. Meantime one can only hope that some day the community will awake to the fact that criminals, with rare exceptions, are not born but made, and will set to work in earnest to unmake them.

The Viscosity of Aqueous Solutions. (A contribution from the Mathematical and Physical Section). By **Charles E. Fawsitt**, Ph.D., D.Sc., University of Edinburgh.

[Read before the Society, 27th January, 1904].

Liquids are distinguished from gases and solids by having a definite volume, but not a definite shape: a liquid has a form according to the shape of the vessel containing it. Different liquids accommodate themselves to a change of form at very different rates: this is due to an internal friction or viscosity coming into play.

The method of measuring the viscosity of a liquid is to allow the liquid to flow through a cylindrical capillary tube under a given pressure, when the viscosity may be calculated by means of the formula $\eta = \frac{p\pi r^4}{8lv}$, where η is the value of the viscosity, v the volume of liquid that flows out in unit time, r the radius of the tube, l the length of the tube, π the number 3·1415..., and p the pressure.

It is rather a difficult matter to obtain good cylindrical capillaries, which are necessary to give satisfactory results, but instead of determining the absolute viscosity we may for many purposes use the relative viscosity, the viscosity of the liquid compared with water (taken as unity). I propose to confine myself to a study of viscosities in their applications to chemistry, and for this purpose relative determinations are quite sufficient. The form of tube used for such relative determinations is that introduced by Ostwald. The pressure used is that of a column of the liquid itself; the capillary is in a vertical position, and the time which a given volume of liquid takes to flow through the capillary is noted. The tube is placed in a thermostat which has two parallel glass plates, front and back, in order that the time of flow at constant temperature may be conveniently observed.

For viscosity measurements the temperature must be kept constant to ± ·05° *C*.

With increasing temperature the viscosity of liquids decreases by about 2% of its value for each degree centigrade. We have the following formula for the calculation of the viscosity; $\eta = \frac{st}{s_0 t_0}$ where η is the viscosity, s and t are the density and and time of flow for the given liquid, s_0 and t_0 are the same quantities for water.

Some interesting relations have been found to exist between the viscosity of liquids and their composition, but this communication is in connection with the viscosity of aqueous solutions. We shall consider solutions which are never more concentrated than about 2-molecular. Solutions more concentrated than this are usually abnormal in other properties, and are also abnormal in their viscosity values.

Substances in aqueous solution may be divided into two classes, electrolytes and non-electrolytes. The electrolytes are partially split up into ions when in aqueous solution, the non-electrolytes are not so split up. We should *a priori* expect simpler results from non-electrolytes, and we shall consider them first.

THE VISCOSITY OF SOLUTIONS OF NON-ELECTROLYTES.

Aqueous solutions of non-electrolytes have always a viscosity greater than that of water, no matter whether the viscosity of these substances themselves (should they be liquids), is greater or less than that of water. Not only does this qualitative relation hold good, but the viscosity of such solutions increases along with the concentration of the solution so that we can represent the relation with the formula $\eta_x = A^x$, (1), where η_x is the viscosity of a solution of concentration x and A is a constant. I shall illustrate this by an example giving the experimental values and those obtained by calculation from the above equation under columns η_1 and η_2 respectively.[1]

ACETAMIDE.

Concentration.	η_1		η_2
$\frac{1}{8}$ mol.	1·013	...	1·014
$\frac{1}{4}$,,	1·028	...	1·028
$\frac{1}{2}$,,	1·057	...	1·057
mol.	1·117	...	1·118
2 ,,	1·250	...	1·250

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[1] The author's paper; Proc. Roy. Soc., Edin. *25*, 51 (1903-4).

Another formula has been suggested as giving a good approximation to the experimental results, namely $\eta_x = 1 + ax$, where a is a constant, but it will be seen that this is just a particular case of (1) when x is small and a also small.

Let us now consider electrolytes.

THE VISCOSITY OF SOLUTIONS OF ELECTROLYTES.

We cannot draw any hard and fast line between electrolytes and non-electrolytes. There are poor electrolytes which conduct the current feebly and these follow the same law as before. With good conductors such as salt solutions we find, however, occasionally variations from the above conditions. Solutions of some salts have a smaller viscosity than that of water. This condition has been called "negative" viscosity. Before discussing this case further we shall consider the viscosity of mixtures of substances in aqueous solution.

VISCOSITY OF SEVERAL SUBSTANCES IN SOLUTION.

A solution of two substances each of which alone gives results which can be represented by the formulæ $\eta_x = A^x$, $\eta_y = B^y$ has a viscosity which is given by the equation $\eta = A^x B^y$. For three substances present in the concentrations x, y and z and having viscosity constants A, B and C, $\eta = A^x B^y C^z$. An electrolyte in water is split up into two or more ions. If we suppose that the undissociated molecule and the ions have particular viscosities of their own, then the viscosity of an electrolyte should follow the equation $\eta = A^x B^y C^y$ if composed of two univalent ions having viscosity constants B and C, and an undissociated molecule having a viscosity constant equal to A. If z be the total concentration of the electrolyte, and a the fraction ionised, our equation becomes $\eta = A^{z(1-a)}(B.C)^{az}$. By the help of such formulæ it is possible to determine the value of the viscosity constant for the ions.[1] These values are in many cases less than unity, and the *negative* viscosity found in some electrolytes is due to the negative viscosity of one or both of the ions.

By comparing the viscosity constants and the migration velocities of the ions, we find that the relation existing between them is approximately one of inverse proportion.

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[1] *Euler*; *Zeit. für Physikal. Chemie*, 25, 536.

THE EFFECT OF CHEMICAL COMBINATION ON VISCOSITY.

The formula $\eta = A^x B^y$ holds for two substances which do not combine chemically. If however there is some chemical action between the substances, the value found for η is different from the calculated value. Conversely we may use such a change in the viscosity as evidence of salt formation when this is not so clearly seen by a chemical examination.

RELATION OF VISCOSITY TO CHEMICAL COMPOSITION.

There has hardly been sufficient work yet on viscosities to state whether there is any close connection between the viscosity of a substance in solution and its chemical composition. For such relations we usually study the change of the property in a homologous series. It is obviously better for our present purpose to study solutions of non-electrolytes. I give here some results I have obtained from three amides.

Temp. 25°*C.*

	Viscosity Constant.
Carbamide, $CONH_2NH_2$, - - -	1·045
Methylcarbamide, $CONH_2NHCH_3$, -	1·142
Ethylcarbamide, $CONH_2NHC_2H_5$, -	1·238

The difference between successive numbers is constant, showing that to some extent the viscosity of solutions is an additive property.

RELATION TO ELECTRICAL CONDUCTIVITY.

There is a very close connection between these two properties. On adding a non-electrolyte to an electrolyte, the way in which the conductivity decreases is exactly parallel with the manner in which the viscosity increases.[1] Again, the temperature coefficients of the two are practically identical.[2]

RELATION TO REACTION VELOCITY.

The case which shows this most distinctly is the change of rate of the reaction,[3] $COS + H_2O = CO_2 + H_2S$, by the addition of certain salts (normal solutions). If K is the velocity constant, we have:

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[1] Proc. Roy. Soc. Edin. *25*, 51.

[2] *Phil. Mag.*, 6 III., 487 (1902).

[3] *Zeit. für Physikal. Chemie*, *23*, 123.

	$K \times 10^6 \times \cdot 4343$	Viscosity.
Water,	527	1·000
$BaCl_2$,	514	1·123
$SrCl_2$,	497	1·141
$CaCl_2$,	481	1·156

The decrease in velocity is not proportional to the increase of viscosity, but there is evidently a connection between the two.

Finally I should like to refer to the use which viscosity determinations have in physiology. It is possible by determinations of viscosity[1] of liquids in the process of digestion to follow the course of this. It is probable that the use of viscosity determinations in physiological problems will be greatly extended in the near future.

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[1] *Zeit. für Physiolog. Chemie,* 35, 465 (1902).

Notes on Physical Apparatus. (A contribution from the Mathematical and Physical Section). By H. STANLEY ALLEN, M.A., B.Sc. :—

(i) "*An Apparatus for illustrating the Composition of Velocities.*"
(ii) "*An Electro-Plating Brush.*"

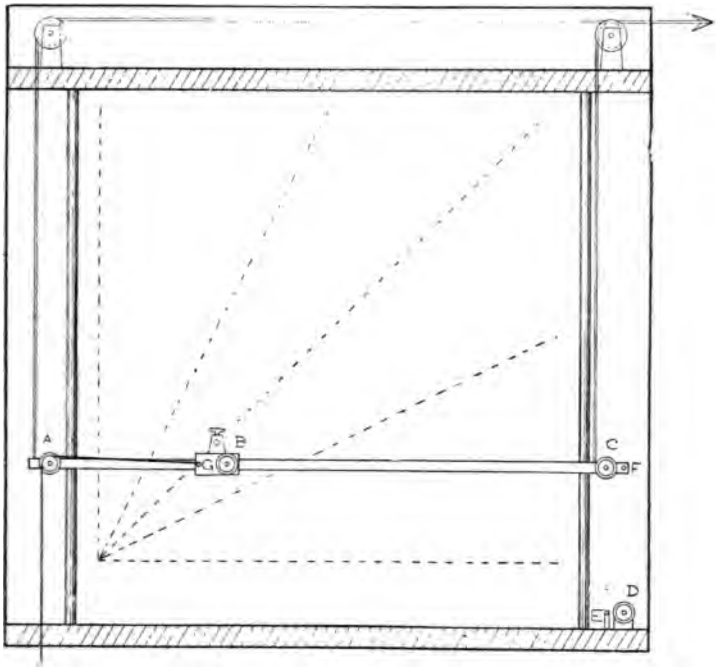
[Read before the Society, 27th January, 1904].

I. AN APPARATUS FOR ILLUSTRATING THE COMPOSITION OF VELOCITIES.

TEACHERS of Mechanics find that many students are capable of grasping facts put before them in concrete form far better than they are able to realise abstract propositions. The apparatus described in the present note was devised for the purpose of illustrating the way in which Displacements, Velocities, or Accelerations in different directions, may be combined together, to give a single resultant Displacement, Velocity, or Acceleration, in accordance with the so-called "Parallellogram Laws." With the object of making clear to the pupil the composition of motion in directions at right angles, several text books on Mechanics mention the case of a ring sliding along a horizontal bar which is being moved vertically upwards. The present apparatus is simply the practical realisation of this illustration, appropriate methods being employed to secure a horizontal velocity which shall stand in certain simple relations to the vertical velocity. In fact, the only novel feature is the way in which the horizontal velocity is adjusted so as to be equal to, double, or one half of the vertical velocity.

The apparatus will be readily understood on an inspection of the accompanying diagram. AC is a horizontal brass bar of rectangular section, which can be raised or lowered by means of cords passing over pulleys at the top of the figure. At each end of the brass bar there is a vertical guide rod of steel, so that no lateral motion of the bar can take place. B is a sliding piece, also of brass, which can move easily backwards or forwards along the bar. A pen or pencil may be attached to it by means of a simple clamp, if it is desired to trace out the path it takes. By means of a suitable weight, attached to a string which passes over the pulley A on the bar, and has the other end fastened to a pin G, the sliding piece is drawn to the left hand side of the apparatus.

The apparatus is set upright on a table in such a way that the left hand corner projects sufficiently to allow the weight to hang freely. Having seen that the brass bar moves easily on the guide rods and that the slider moves freely on the brass bar, we may first of all trace the co-ordinate axes.



1. *Horizontal Velocity.* To get this, we have merely to draw the slider along the brass bar.

2. *Vertical Velocity.* This is obtained by pulling the cord on the right of the apparatus, and so raising the brass bar with the slider on it.

We may then proceed to show various combinations of these velocities, by constraining the slider to move along the bar at a rate proportional to the rate of motion of the bar itself. This constraint may be applied by means of a cord about twice the length of the bar, each end being provided with a spring hook.

3. *Vertical Velocity one half of the Horizontal Velocity.* Attach *both* hooks to the pin F. Pass both portions of the cord *under* the pulley D on the baseboard, then *over* the pulley C. Then pass the loop of the cord over the pulley B on the slider.

4. *Vertical Velocity equal to the Horizontal Velocity.* Attach *both* hooks to the pin E. Pass both portions of the cord over the pulley C, and then pass the loop over the pulley B.

5. *Vertical Velocity double the Horizontal Velocity.* Attach one hook to the pin E, the other to the pin F. Pass the cord attached to E over the pulley C, and then pass the loop of the cord over the pulley B.

It is clear that other relations between the vertical and horizontal velocities might be obtained by introducing more pulleys, but the cases just given are sufficient for illustrative purposes.

If it is desired to trace the path taken by the slider, it is better to use three cords, one for each of the cases considered above. The length of the cord may then be adjusted so that the slider always starts from the same point. It is well to distinguish the pins E and F by different colours, and to mark the hooks on the three cords to correspond.

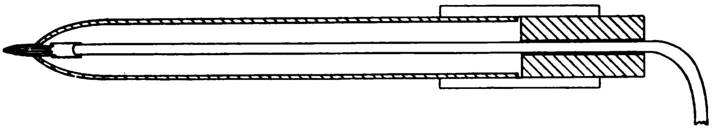
Although we have here described an apparatus complete in itself, this is by no means essential. An experiment in all respects similar can easily be arranged with the use of articles that should be available for every teacher of mechanics. With the help of a few pulleys, a broomstick for the horizontal bar, a brass ring to slide on the stick, and a ball of string, the laws of the composition of motion can be illustrated before a class in a convincing form.

II. AN ELECTRO-PLATING BRUSH.

In the construction of a dividing engine for ruling diffraction gratings, the greatest possible accuracy is required. Rowland has shown that a periodic displacement of one millionth of an inch in ruling a grating with 20,000 lines to the inch will produce visible "ghosts" in the third spectrum. The only method of constructing such an engine, that has so far proved entirely satisfactory, is by means of a screw turned by a pawl and rachet wheel. The genius of Rowland has given us a method by which it is possible to obtain a screw that is for practical purposes, perfect. In his machine the periodic error was entirely due to the graduation and centering of the head. This error was corrected mechanically by means of an attachment to the nut.

Lord Blythswood is endeavouring, in his dividing engine, to avoid such a mechanical correction by correcting the individual teeth of the ratchet wheel. If a tooth is too wide, the superfluous material is removed by filing or burnishing the face against which the pawl bears, but if a tooth is too narrow some difficulty arises. In order to increase the width of the tooth, the plan originally adopted was to bruise out the face of the tooth by hammering on the top. To this method there are obvious objections, more especially in the uncertainty as to the magnitude of the effect produced. It occurred to me that the difficulty might be overcome by electro-plating the face of the tooth, and it was for this purpose that the electro-plating brush was designed.

The apparatus is constructed in the form of a pencil or brush, to be applied to the surface that is to be plated. It consists of a tube charged with the liquid that is used as the electrolyte. One end of this tube is closed by a cap, to which is attached a flexible wire by means of which connection is made with one terminal of the electro-plating battery. The other end of the tube is partially closed by a wick or brush to be placed in contact with the surface to be electroplated. The anode is formed of the metal with which it is desired to plate the surface. It is attached to the cap, and dips into the liquid in the interior of the tube. Or, if it be preferred, the tube itself may form the anode. The surface to be plated forms the kathode.



In correcting the ratchet wheel the teeth that require plating are cleaned with caustic potash followed with sulphuric acid. A drop of the electrolyte is placed in the tooth, and the electroplating brush is applied for a time depending on the additional thickness required. Using a two volt cell as the source of current the time taken may vary from one to ten minutes. The process is slow, but its great advantage lies in the fact that the effect is fairly well under control. If proper care is taken in cleaning the teeth before they are plated, the results appear to be sufficiently permanent.

It will be seen that the electro-plating brush confers the ability to plate any selected area on a metallic or other conducting surface. It is possible that it might prove useful for decorative purposes, as I find that one can paint any design on the conducting surface simply by passing the brush over the surface as though one were using an ordinary paint brush. In this case the voltage employed can be considerably increased without producing the overheating that would occur if the brush were stationary.[1]

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[1] It appears that this process has been anticipated. An expired patent (No. 15365, Nov. 21st. 1884) secured by Dr. Gottfried Wagener and Curt Netto of the University of Tokio, describes a process and apparatus for electroplating by making the article to be plated the fixed pole of a galvanic battery, while the other pole together with the corroding liquid is made portable, so that it may be conducted over the surface of the article.

The Stability of Flying Machines. (A contribution from the Mathematical and Physical Section.) By W. E. WILLIAMS, B.Sc.

[Read before the Society, 27th January, 1904.]

THE subject of artificial flight is one which has appealed to the inventive genius of mankind since the earliest times, and many attempts have been made from time to time to obtain the mastery of the fickle element in which we live. The history of these early attempts furnishes some very amusing reading, I will only mention one projected machine, which was in a way very successful. It was invented by a Portuguese of the name of Lourenco, aoout two hundred years ago. This machine was a very simple contrivance it resembled an ordinary boat with the sails set horizontally above the deck, each of the crew was supplied with a pair of bellows, by means of which they raised the wind, and of course the wind raised the ship. Lourenco laid his designs before the king, and in recognition of his genius he was immediately appointed Professor of Mathematics with a salary of £3,750 a year. Since his time many people have spent thousands on flying machines, but I am not aware that anybody except this gentleman ever made anything out of them.

The flagrant violation of dynamical laws which is seen in this machine has unfortunately been characteristic of æronautical matters all along, and it is only in quite recent years that some of the apparently obvious bearings of Newton's Laws have been perceived. I propose to-night to discuss briefly the dynamical laws governing flight, and the difficulties which arise from them, and to draw special attention to one difficulty which is at present the most pressing one, the difficulty of balancing the machine while in the air.

The first and most important difficulty which was met with was that of obtaining the power necessary for propulsion and support. We may first state that the power necessary for supporting a given weight in the air, is not a fixed quantity, but depends on the method by which support is obtained. This will be seen by considering the way in which the support is obtained, namely, by the reaction of the air.

Newton's third law of motion will be familiar to all of you, it states that action and reaction are equal and opposite. The reaction of the air which is the force supporting the machine is equal to the momentum of the air set in motion in each second, mv. Now the energy of this motion, that is to say the power which must be expended, to keep the machine up is $\frac{1}{2}mv^2$, that is to say, force × $\frac{1}{2}v$, and this may be made as small as we please by diminishing v, at the same time increasing m so as to keep the product mv constant. We therefore see that the most efficient machine is one which acts on as large a mass of air as possible.

Now the usual method of obtaining the necessary reaction is by means of a moving surface acting on the air. There are two ways in which we can make such a surface act on a large mass of air. First by making the surface itself very large, and also by making it move rapidly in the direction of its plane so that the surface is continually coming in contact with undisturbed air. If as has often been proposed an airship were to be raised by means of a vertical propeller, the propeller in order to be efficient would have to be very large, and this shows why such machines have always been failures. Such a propeller is a very different affair from a ship's propeller, for the motion of the ship is continually bringing the blades of the propeller into contact with undisturbed water, while of course a flying machine is not designed for rapid motion in a vertical direction. There is one other point which might appropriately be considered here, the question of dimension or size of a machine. If we have two similar machines of different size then the weight of the machines will be proportional to the cube of the linear dimension, while the area of wing will be proportional to the square of the same dimension, thus the smaller machine will have more supporting area per unit of weight. This fact explains the difference between the mode of flight of an insect and of a bird. The insect supports itself by a method which is practically equivalent to a vertical propeller, and as we know, an insect is able to remain stationary in the air, a feat quite beyond the powers of all but the smaller birds. A machine capable of supporting a man must of course be much heavier that the heaviest bird and this method of obtaining support is quite impracticable, and we must therefore have recourse to the other method mentioned, namely by making the supporting surface move forwards rapidly so as to bring it continually in contact with undisturbed air. The type of machine which finds most favour at present is one in which the supporting surface is rigidly attached to the machine, and is slightly inclined to the direction of motion.

The adoption of this type has practically solved the question of power, as will be seen from the following table taken from Langley's Aerodynamics. It gives the power necessary to sustain a flat plane at different velocities. You will see that we have a rather paradoxical result, that the power necessary to drive such a plane is smaller the greater the velocity.

Angle α	Speed. Feet per Sec.	Weight Sustained per H.P.	Work done in Driving Plane.
15°	36·7	58 lbs.	623 ft. lbs.
10°	40·7	77 "	474 " "
5°	49·8	122 "	297 " "
2°	65·6	209 "	174 " "

You will also notice that at a speed of 45 miles per hour one h.p. will sustain 200 lbs. which is a very encouraging result seeing that engines can be made to weigh less than 20 lbs. per h.p.

The use of aeroplanes or aerocurves for support, however, introduces another difficulty, namely that of balancing, and it is this difficulty which at present stands in the way of successful flight. To see how this difficulty arises let us consider a little more minutely the forces acting on such a surface. The diagram represents a lamina, *A B*, moving in a horizontal direction, with velocity v, its plane making an angle α with this direction. It has been found experimentally that the air resistance to the lamina may be represented by a force $R = ksv^2f(\alpha)$ acting in a direction normal to the plane of the lamina, k = const, s = area of surface, v = velocity, $f(\alpha)$ is a function of (α), the form of the function depending on the shape of the surface.

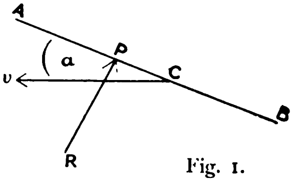

Fig. 1.

The diagram Fig. 2 shows the form of the function $f(\alpha)$ for various surfaces. You will notice that at small angles of inclination the force on a curved surface is much greater than the force on a plane surface at the same angle. For this reason curved surfaces are now generally used in gliding machines. The force R does not act at the centre of the lamina AB, but at some point in front of the centre such as P. The point P is generally called the centre of pressure. The distance of P from the centre c depends on the angle of inclination (α), we may represent it as $b = a\,\phi(\alpha)$ where a is the breadth of the plane. For square planes the form of $\phi(\alpha)$ has been found by Jöesel to be given by $\Phi(\alpha) = \cdot 6\,(1 - \sin\alpha)$.

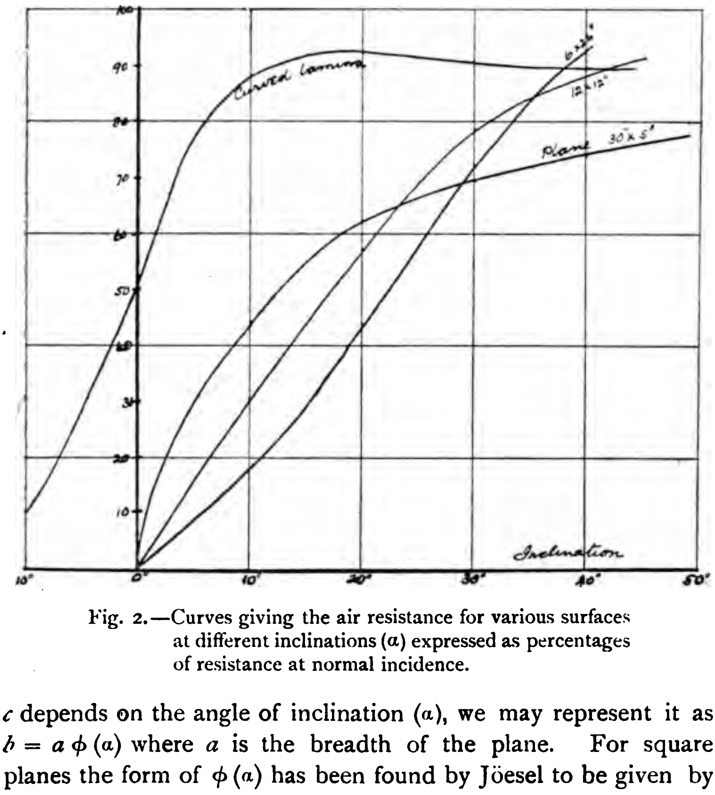

Fig. 2.—Curves giving the air resistance for various surfaces at different inclinations (α) expressed as percentages of resistance at normal incidence.

The forces acting on the lamina are (1) the resistance R acting through P; (2) the weight acting through the *c.g.*; (3) the propelling force.

In order that the machine should fly steadily it is necessary that these forces should be in equilibrium. The conditions of equilibrium are (1) that the sum of the vertical and horizontal components should be zero. (2) That the moment of the forces about the *c.g.* should be zero.

Now the weight has no moment about the *c.g.*, and we may also suppose that the propelling force passes through the same point, the last condition is therefore satisfied if the centre of gravity is in the line of the force R. This and the first condition can easily be satisfied (for particular values of velocity and inclination) in designing the machine, and the machine may then be said to possess a mode of steady motion. Something more than this, however, is required, it is necessary for successful flight that this steady motion should be stable, that is to say, if the steady motion is disturbed, as it easily may be by a gust of wind, it is necessary that the machine should be capable of righting itself, or if there is a man on it that he should be able to right it, and it is here that the difficulty comes in. Supposing first that there is no man on the machine let us examine what are the conditions that the equilibrium should be steady.

In the present state of mathematical knowledge, it is impossible to solve directly the problem of a lamina moving through the air. If, however, we assume experimental values for the functions $f(\alpha)$, $\phi(\alpha)$ as found by means of whirling machines, we may treat it as a problem in rigid dynamics, and the question of stability for small oscillations admits of an easy solution, though the problem of stability for large oscillations is still rather difficult.

Taking first the case of a plane moving freely under gravity we may write down the equations of motion referred to axes moving with the plane.

$$m(u - v\dot{\theta}) = mg\cos\theta - R.$$
$$m(\dot{v} + u\dot{\theta}) = mg\sin\theta.$$
$$mk^2\ddot{\theta} = Ra\phi(\alpha).$$

For steady motion.

$$mg\cos\theta = R, \quad mg\sin\theta = 0.$$
$$Ra\phi(\alpha) = 0.$$

Now suppose these conditions fulfilled and the lamina to be moving steadily through the air, it suddenly meets with a gust of wind, the effect of this is to alter all the three co-ordinates u, v, θ. To find the subsequent motion let us represent the altered velocities by $u = u_0 + \delta u$, $v = v_0 + \delta v$, $\theta = \theta_0 + \delta\theta$; u_0, v_0, θ_0 denoting the original values.

We now substitute these values in the above equations, and we thus get three differential equations for δu, δv, $\delta\theta$. These may be solved by putting $\delta u = P\epsilon^{\lambda t}$, $\delta v = Q\epsilon^{\lambda t}$, $\delta\theta = R\epsilon^{\lambda t}$, where P, Q, R, are constants.

If these constants are eliminated we get an equation to find λ.

This equation is of the fourth degree and may be written $A\lambda^4 + B\lambda^3 + C\lambda^2 + D\lambda + E = 0$. This equation has four roots and the signs of these roots determine the character of the motion.

Suppose in the first case that we have a real positive root, then $\delta u = e^{\lambda t}$, $e^{\lambda t}$ increases with t and therefore the disturbance in u continually increases and the system finally departs from the steady motion.

If, however, the root be negative the disturbance continually decreases and the system settles down again to the steady motion.

Besides these two cases we may have complex roots coming in *i.e.*, roots of the form $\lambda = a + b\sqrt{-1}$.

These roots can only occur in pairs, and represent an oscillatory motion. If the real part of these roots be positive, the amplitude of the oscillations continually increases and the motion is unstable, while if the real part be negative the oscillations continually diminish and the motion is stable. In order, therefore, that the motion should be stable it is necessary that the real roots and the real part of the imaginary roots should be negative.

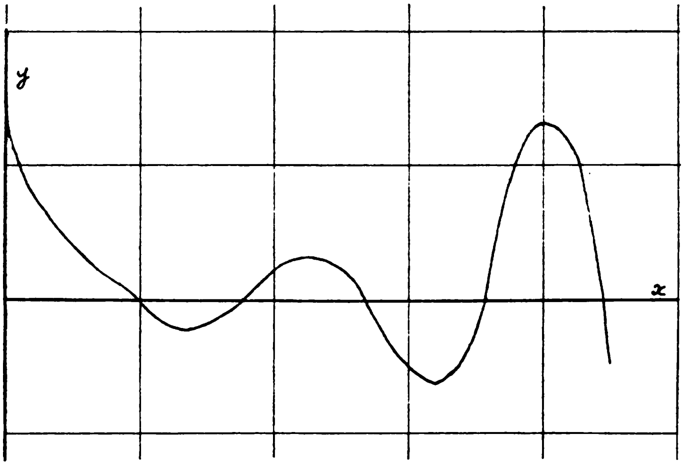

Fig. 3.—Path of glider (calculated).

$$v = e^{-2\cdot 7t} + \tfrac{1}{2}\,e^{-17t} + e^{1\cdot 2t}\cos 7t.$$

In a paper[1] by Dr Bryan and the present writer, these criteria were applied to the case of some simple systems—gliders made up of one or two planes, and it was found that in general the motion is stable if the velocity exceeds a certain critical value. Thus for a square plane balanced to fly at an angle of 10° with the horizontal, it was found that for stability V^2 must be $>800a$, where a is the half breadth of the plane, the units being feet and seconds. For a value $V^2 = 100a$ the roots of the λ equation are $-2{\cdot}7$, $-17{\cdot}7$, and $1{\cdot}2 \pm 7\sqrt{-1}$. These give a curve similar to Fig. (3).

The best form of flying machine will be one for which the critical value of V^2/a is small. If there be a man on the machine it is not absolutely necessary that the machine should be stable.

Many of the gliding experiments which have been made by Libeuthal, Chanute, Pilcher, and others may not improbably have been made with machines, which were unstable, and were only kept balanced by the skill of the aeronaut. In order that this may be possible it is necessary that the departure from steady motion should be slow so that the experimenter may have time to move so as to preserve the balance. This requires that the real parts of the roots of the period equation if positive should be small, and the smaller they are the easier will it be to keep the machine balanced.

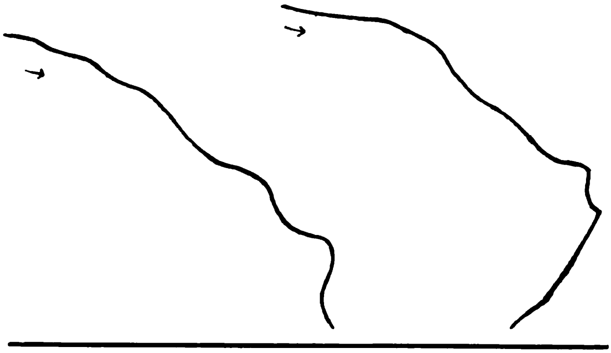

Fig. 4. Fig. 5.
Path of glider. Two square planes at an angle.

In order to illustrate the theory of the motion of gliders developed above, photographs were taken of the paths of little paper gliders gliding across a room. A small piece of magnesium was attached to the glider and was lighted when the glider was thrown. Some of these photographs are reproduced in Figs. 4, 5. In many of them two distinct sets of oscillations may be traced, and in Fig. 5 it is very clear that the small oscillation increases and finally upsets the glider.

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[1] *Aeronautical Journal*, January, 1904.

CENTENARY LECTURES, No. III.

Advances in Chemical Industry during the Nineteenth Century.

By GEORGE T. BEILBY.

[Prepared by request of the Council, and delivered before the Society, 10th February, 1904.]

OF the chemical industries of the Nineteenth Century it may be said in the language of Malvolio—"Some were born to science, some achieved science, and some had science thrust upon them."

The scientific birth of chemical processes is essentially a development of the nineteenth century. The alkali processes, the processes for the making of coal tar colours, of nitro-glycerine and gun cotton, of cyanides and ferrocyanides, were scientifically conceived before they appeared in their fully developed industrial forms. On the other hand, iron and steel making, soap boiling and candle making, brewing and distilling, and many other operations had their beginnings as empirical arts and crafts, and were based on no general scientific principles.

These old industries have, during the past century, absorbed the science of the time in various ways and in varying degrees. Of some it may be said that they have "achieved science," of others that science has been "thrust upon them." Of very few can it be said to-day that they are altogether without science, and may we not hope that before many years are over the necessity for the thrusting of science on unwilling workers will no longer exist.

In the early years of the century the influence of chemical and physical laws were only recognised in a few manufactures, and these mainly associated with the production of the strong acids and alkalis. The production of pharmaceutical preparations was mainly in the hands of the individual pharmacists, who, working from the collected recipes of the past, continued to produce salts and metallic preparations, and the crude alcoholic or watery extracts of roots, leaves or flowers with little or no appreciation of their chemical possibilities.

In the latter department the great advance made during the early part of the century was mainly in the separation from these crude extracts of the active principles to which they owed their therapeutic value. To the pursuit of this branch of study we owe immense additions, which were made in the earlier part of the century to the number of well-defined organic substances whose chemical composition had been accurately ascertained by organic analysis. The vegetable alkaloids, quinine, cinchonine, morphine, codëine, strychnine, brucine, and many others were thus isolated and studied. The name "organic chemistry" suggests that the great branch of the science which still goes by that name had its origin in the study of the products of animal and vegetable life. This study was the first and necessary step towards the great development of synthetic chemistry and the wider study of the compounds of carbon. But the name, organic chemistry, as applied to this larger whole, is somewhat narrow and misleading.

In the preceding lecture of this course, Professor Henderson explained to us the part which the theory of the *constitution* of chemical compounds has played in modern synthesis. I will therefore merely remind you of the important contribution which the study of the constitution of natural products like quinine, morphine, nicotine, alizarine, indigotin, etc., has played in the establishment of the knowledge and practice of organic synthesis. This knowledge enables the synthetic chemist of to-day to build up new substances from a comparatively few simpler materials, with a very fair amount of confidence that the new bodies will have certain desired properties. For example, he may work for the production of a new colour, a new febrifuge, a new antisceptic, or a new photographic developer.

The individual pharmacist or dyer no longer produces the raw materials of his art by crude and wasteful processes carried out in the back yard of his establishment. Specially equipped works have been organised for the manufacture of these materials, and not merely for the reproduction of the old, but also for the production of a continual stream of new substances.

The special home of this branch of industry is in Germany, and it will always be a matter for regret that the British chemical manufacturer lost for the nation the great industrial opportunity which presented itself when the aniline colours were first presented to the world by Dr W. H. Perkin, an Englishman working in England. There is some consolation for us in the knowledge that in the manufacture of certain natural products like quinine and morphine the British manufacturer still keeps an important place. The Howards of London, and the Smiths of Edinburgh, are still with us, and the results of their skill and energy show what the much abused British manufacturer can do if he cares to try.

The pharmacist has given place to the manufacturer not merely in the preparation of organic products but also in the making of inorganic compounds like acids, alkalis and metallic salts.

This transference took place at an earlier date in the case of the latter class of substances because of the springing up of the greater demand which resulted from their increasing use in the arts. The strong acids, sulphuric, nitric, and muriatic, and the alkalis, potash and soda, were being more and more extensively used in dyeing and printing, and in soap-making and glass making.

Even as early as the end of the eighteenth century the need for larger and cheaper supplies of alkali had been felt. At that time the only sources of the alkalis potash and soda were the ashes of plants and seaweeds and certain salt lakes which existed in the comparatively rainless parts of the world. The alkali made from these sources was necessarily costly, and the supply was limited by various local conditions. In the year 1775 the French Academy of Science, realising the disadvantage to industry which resulted from the dearness and scarcity of alkali, and realising also the inexhaustible stores of raw material which existed in common salt, offered a prize for the most economical process for the conversion of common salt into soda. This prize was ultimately awarded to Nicolas Leblanc, whose process may fairly be classed among those which have been "born to science." Its continued and vigorous existence for 113 years has amply justified the conditions of its birth, for it has been well said that the process as produced by its inventor, covered all the essential principles which underlie its operation in the most advanced practice of to-day.

A patent was granted to Leblanc in 1790, but the practical development of the process was slow, partly, no doubt, owing to the troublous times on which it had fallen. Leblanc died a poor man before his epoch-making process had unfolded its great possibilities.

The process was built on the magnificent foundation of a cheap and unlimited supply of its chief raw material. Salt as it occurs in sea water is equally available on any of the shores of the ocean, but as the production of 1 ton of salt involves the evaporation of about 30 tons of water, its manufacture from this source is only resorted to where the climate is dry enough to permit of natural evaporation by sun and wind. In England the extensive salt deposits of the Northern Counties afford such cheap and available supplies of strong brine that the alkali industry has, from the first, made its home either on the Tyne in the East, or on the borders of Cheshire and Lancashire on the West. For the greater part of last century the Alkali Works of the north of England manufactured soda ash and bleaching powder for the greater part of the world's requirements. The proximity of the great coal fields of Lancashire and Durham and the unequalled shipping facilities afforded by the Tyne and the Mersey enabled the alkali makers of England to hold this leading position so long as the Leblanc process kept its place as the best and cheapest method of production. Up till the last quarter of the century the chemical industry of the country included very little besides the alkali and its immediately allied industries. We are justified, therefore, in devoting a good deal of our attention this evening to this, the largest and most typical of the British chemical industries.

The history of this industry may be naturally marked off into three periods by the advent of the three characteristically different processes of Leblanc, Solvay, and Castner. In each the primary object was the same, namely to produce soda ash, or carbonate of sodium, from salt or chloride of sodium. Of these three periods the first will always be the most interesting to the chemist, for though Nicolas Leblanc certainly laid down the broad simple outlines of the process, the practical working out of its details and of the subsidiary processes with which it had to be associated afforded a wonderful field for chemical engineering and economic skill. This great field has been nobly occupied by a succession of leaders and inventors of whom England may justly be proud. Long may the history of these times be preserved, and often may it be repeated in the ears of the chemists of the coming generation. One is sometimes tempted to fear that the rapid modern development of improved means and appliances of all kinds, and the more wide spread and accurate knowledge of scientific laws which have come within easy reach of students of very ordinary capacity may lead us to forget or to esteem too lightly the problems attempted and the successes achieved by the workers of the past generation. It is good for us not only to *know*, but also to *feel* that "there were giants in those days."

The raw materials of the Leblanc process are salt, limestone, coal, and sulphuric acid. Its product is soda ash, and its by-products are hydrochloric acid and sulphide of calcium. It may safely be said that it has been on the by-products that the greatest amount of skill and labour have been expended. So long as the process was conducted only on a relatively small scale the disposal of the by-products gave no great trouble. Hydrochloric acid was a saleable article, and sulphide of calcium was light-heartedly tipped on any convenient piece of waste land. But as the manufacture grew to meet the increasing demand for soda ash it began to be realised that the future of the process must largely depend on the by-products. In the case of the sulphur it will be noticed that while it is introduced into the process in the highly elaborated form of sulphuric acid, it is finally dismissed as the worse than useless sulphide of calcium. On the recovery of sulphur from the sulphide of calcium or alkali waste as it is called, an immense amount of money and skill have been expended, unfortunately without any profitable result. The comparatively low price at which the sulphur for sulphuric acid-making could be obtained by burning iron or copper pyrites left a very small margin for its recovery from alkali waste. Sulphur recovered from the waste was certainly made and sold, but the broad fact remained that the great heaps of waste continued to grow and to become more and more of a nuisance in the neighbourhood of the alkali works. It is to the alkali waste heaps at St. Rollox that we are indebted for the well marked flavour of sulphuretted hydrogen which pervades the city during certain states of wind and weather.

With the other by-product, hydrochloric acid, the case has been somewhat different. The uses for the acid as such extended side by side with the growing production, but in many cases it was treated as a waste product and was allowed to escape into the atmosphere uncondensed. To render the escape of these acid gases as innocuous as possible, very high chimneys were built, and from the top of these the deadly gases were spread broadcast over the country. In consequence the alkali works became centres of desolation, the vegetation being blighted for many miles round. Commenting on this state of things in 1886, Mr E. K. Muspratt said: "The present generation can hardly form an idea of the intensity of feeling and prejudice aroused against the alkali works during the first forty years of their existence, that is up to the passing of the Alkali Act in 1863."

The passing of this act marked the beginning of a better state of things. Under the able and tactful administration of the late Dr Angus Smith, the first chief inspector, and of his successors, Mr A. E. Fletcher, and Mr R. Forbes Carpenter, the ingenuity and skill of the chemists and engineers of the alkali works have been stimulated in a most healthy way. The annual reports of the chief inspector and of the various district inspectors form an invaluable history of the development of the Leblanc industry on this side. The inspectors have in the main been regarded as the helpful friends and advisers of the manufacturers, a position which their wide and varied experience, gained in the many works under their charge, enabled them to fill in a very exceptional way. By steadily applying a moderate pressure to the manufacturers, while at the same time entering into and fully understanding their difficulties, a reform has been brought about which at one time could hardly have been hoped for. From the last annual report we learn that the total number of works registered under the Alkali Acts is 1,169. Every one of these is regularly visited and inspected generally more than once during the year. In 1902, 4,946 visits of inspection were paid in England, Ireland, and Wales, and 506 in Scotland. No more striking tribute could be paid to the value of the Acts, and to the tact and skill with which they are administered, than is afforded in one simple sentence which I will quote from the report on the works registered in Scotland. In presenting the report of Mr Curphey, the inspector for Scotland, Mr Forbes Carpenter says:—"Again it is satisfactory to be able to record the fact that the supervision of the various chemical operations described by Mr Curphey, has been effected without resort to prosecution of any work for infringement of any of the penal clauses of the Statute of 1881."

This state of things can only be regarded as a triumph of good legislation wisely administered. On more than one occasion I have urged that the general purification of the air of our towns and manufacturing centres should be set about in the same wise spirit, and by the same commonsense methods. Undoubtedly the smoke problem is much more complex and serious than the alkali works pollution, mainly because it is so wide-spread, but the encouraging records, and the invaluable administrative experience gained under the Alkali Acts ought to supply the necessary courage and inspiration to those who are working for this reform.

As the demand for soda ash increased, the disposal of its by-product, hydrochloric acid, become a more and more pressing problem. The commercial production of bleaching powder from the chlorine of the hydrochloric acid came as a most welcome outlet for this by-product just when the pressure had become most acute. I believe that when this manufacture was first carried out by Mr Tennant at St Rollox, the chlorine was prepared by heating together salt, sulphuric acid, and peroxide of manganese, that is to say, quite independently of the soda ash manufacture, the chlorine being the chief product, not the by-product of the process. But the increasing production of hydrochloric acid by Leblanc Works led to its use directly for the production of chlorine. Peroxide of manganese was still required for the liberation of chlorine from the hydrochloric acid, and so long as the chloride of manganese had to be treated as a waste product this raw material added considerably to the cost of the chlorine. The economical regeneration of peroxide from chloride of manganese, therefore, became an important problem. Again the lead was taken at St Rollox by the ingenious process of Mr Dunlop. The lead having been given was soon followed in other places, but full success was not achieved till Mr Weldon evolved his beautiful process in the works of Mr Gamble at St Helens. The economic effect of this process was at once felt, and the cheaper production of bleaching powder soon led to a greatly extended consumption for the bleaching of rags and other papermaking materials.

It is important to realise the inter-dependence of the outputs of soda ash and hydrochloric acid by the Leblanc process. Theoretically for every 58½ tons of salt decomposed, 53 tons of soda ash, and 35½ tons of chlorine must be produced. If the whole of this chlorine were converted into bleaching powder it would produce about 100 tons. The Leblanc soda maker must provide for the disposal of this chlorine innocuously, and if possible, profitably. It must be sold as hydrochloric acid, as bleaching powder, or as a chlorate, or it must be run away in an innocuous form after neutralization with lime or other base. Up to that point of production at which the whole of the chlorine can be profitably disposed of, Leblanc soda ash can hold its place against all rivals, but the moment the chlorine becomes a source of loss or of actual outlay, the cost of the soda ash rises to a prohibitive point. This condition necessarily imposes very narrow limits on the production of soda ash; limits either of output or of price. In 1878 the selling price of soda ash was about £6 per ton, and of bleaching powder £5, while hydrochloric acid only fetched about 10s. per ton. Any increased output of soda ash could, therefore, only have been made at an increased cost.

Fortunately for the consumers of alkali, the ammonia soda process had by this time reached a thoroughly commercial stage. The chemical reaction between chloride of sodium, and bicarbonate of ammonia had been known to chemists early in the century, but its use in the form of an economical process was only developed in the latter half of the century. Ernest Solway of Brussels took out patents for a commercial process from 1861 onwards. He erected works in Belgium in 1863, and in 1867 the product of these works was exhibited at the Paris Exhibition of that year. From 1872 onwards the success of the process was assured, and large works were erected in various parts of the world. The development of the process in England was due to the skill and energy of Dr Ludwig Mond, and Sir John Brunner, the founders of the well known firm which bears their names.

The feature of this process which made its arrival so opportune was that it could be economically worked without regard to the chlorine of the salt; that is to say, the conditions under which the process was worked allowed for the running away of the whole of the chlorine in the comparatively innocuous form of a neutral solution of chloride of calcium. The maker of ammonia soda was, therefore, in the enviable position of being able to regulate his output by his own convenience and the demands of the market for alkali, untroubled by the existence of unmanageable by-products. Under the impression that the Leblanc process was near its end, great efforts were made by the ammonia soda makers to devise some economical means by which, if need be, the chlorine of their waste liquors might be available for the production of bleaching powder. Had such a process been found, the whole alkali industry might have been appropriated by the ammonia soda makers. But this was not to be, and the two processes continued to exist side by side, each filling a place which the other could not occupy.

The practical realisation of the direct decomposition of salt by electrolysis, which resulted from the invention of the Castner cell, introduced a new factor into the industry, for by electrolysis it became possible to decompose salt into its elements without the production of by-products, or of nuisance of any kind. But the electrolytic, like the Leblanc process, laboured under the disadvantage that the equivalent quantity of chloric *must* be produced for every unit of salt electrolysed. As the alkali industry has been brought before you as being more or less typical of chemical progress during the century, it will be well that we should look a little more closely into the theoretical aspects of the three great process developments which have been already outlined.

Salt or chloride of sodium is, as you are aware, a compound of the two elements sodium and chlorine. Sodium is a metal of the alkali group, and chlorine is a gas and a member of the haloid group of elements. There are probably no two elements which are more unlike in their properties, their tastes, and affinities. Among the elements there is apparently a natural provision that affinity between any two elements is not in proportion to their likeness but to their unlikeness, hence we find between the two dissimilar elements, sodium and chlorine, an affinity of the most intense description. When presented to each other they combine with a great evolution of heat to form that peculiarly stable substance, chloride of sodium. A union which takes place under these conditions is not easily dissolved, indeed the heat which is evolved on combination is an exact measure of the equivalent energy which must be supplied in order to bring about the separation. Though the analogy between the cohesive force of the molecules of a metal, and the chemical affinity of two dissimilar atoms in a molecule of a compound, is not perfect, it may be justifiable to use this analogy for the purposes of illustration. We are all familiar with the terms in which the strength of a metal such as steel or iron is described by engineers; the tensile strength, for instance, is the power of resistance of a rod or bar to a stress tending to pull it asunder. This is generally expressed in tons per square inch of the cross section of the bar at right angles to the line in which the stress is applied. Mild steel of good quality has an ultimate strength of about 25 tons per square inch. Under particular conditions steel may be obtained which has an ultimate strength of 70 or 80 tons. This, I think, may be taken as the upper limit of tensile strength for solids as we at present know them. For the purpose of illustration purely, I have calculated what tensile strength would correspond with the affinity between sodium and chlorine. Obviously, certain assumptions as to the conditions of the molecule before and after separation must be made. Making certain assumptions, which are undoubtedly well within the actual facts, I find that the affinity between chlorine and sodium in salt is equivalent to a tensile strength of 800 tons per square inch, or 100 times as great as the highest degree of cohesion found in the toughest solid we know. Without stretching our assumptions very unduly, a considerably higher figure might be arrived at. So far as we know the intimacy of chemical union is of an entirely different order from that of cohesion as we know it in solids or liquids, I must therefore ask you to take my analogy simply as indicating in a physical form somewhat of the intensity of the force involved in the separation of the elements in salt. The making of soda ash from salt necessarily involves the tearing apart of these closely united elements.

Soda ash is a compound of the metal sodium with the acid radicle CO_3. The problem of the production of soda ash from salt involves the replacement of the powerful acid radicle Chlorine by the comparatively feeble radicle CO_3. The early chemists believed that it was hopeless to attempt to do this directly, therefore Leblanc, like a military strategist, gained his end by a flank movement. Replacing the elementary radicle Cl by the complex, but very powerful radicle SO_4 he obtained the sodium in a more vulnerable combination. The SO_4 radicle is strong only in its complete and corporate condition, but being itself a complex substance it is possible to attack it piecemeal, and to win from it the sodium for the comparatively feeble CO_3. The weakest point of the SO_4 is the affinity between the sulphur and the oxygen. At a red heat the affinity of oxygen for carbon is stronger than its affinity for sulphur, if therefore the sulphate of sodium Na_2SO_4 is heated with carbon, the oxygen is removed as carbon monoxide CO and the sodium is left in combination with sulphur, the acid radicle of hydrosulphuric acid, which under most circumstances is weaker than CO_3. According to the method of Leblanc the sulphide of sodium Na_2S while still in the hot fused condition is brought into intimate contact with limestone or carbonate of calcium $CaCO_3$ when an exchange of acid radicles takes place, the CO_3 going to the sodium, and the S

to the calcium thus :—$Na_2S + CaCO_3 = Na_2CO_3 + CaS$. The flank movement has been entirely successful, at the first step the chlorine has been driven out in the form of hydrochloric acid gas; at the second step the sulphuric radicle has been broken down and weakened by the removal of its oxygen, and as a final step the feeble sulphur radicle has been thrown out and replaced by the carbonic radicle.

In the ammonia soda process the attack on the chlorine is made by the CO_2 directly but not single handed. The ally in this case is not the powerful sulphuric acid, but ammonia the weak "volatile alkali" of the alchemists. Ammonia is a base of fairly strong salt-forming properties, but there is not one of its salts from which it cannot be turned out by the feeblest of the fixed alkalis. In its combination with carbonic acid to form carbonate of ammonia, the mutual affinity is so weak that the salt dissociates into ammonia and carbonic acid, at a temperature considerably below that of boiling water.

When a salt is dissolved in water some of its molecules dissociate into their ions. Chloride of sodium, for instance, gives rise to the separate ions each carrying its equivalent electrical charge thus; $\overset{+}{Na} + \overset{-}{Cl}$. This ionization takes place only to a limited extent, that is to say out of the total number of molecules present in a salt solution of moderate strength only comparatively few are separated into sodium and chlorine ions. If another salt is added to the solution it also becomes partially ionized and union may take place between the ions of the first and second salts. But this exchange of partners comes to a standstill when a certain equilibrium among the different molecules and ions has been reached. If, however, any one of the products of the reaction is insoluble so that it passes out of solution as it is formed, a new equilibrium point is established, and by the continuous addition of the original salts to the solution a continuous separation of the insoluble product will be insured until the new equilibrium point is reached.

If carbonate of ammonia is added to a solution of chloride of sodium a certain exchange of ions takes place, and carbonate of sodium and chloride of ammonium are produced in quantity depending on the equilibrium point of the four salts which the solution now contains. As all four salts are very soluble in water, there is no separation of any of them, and the equilibrium remains undisturbed. The sodium salts are, with hardly an exception, the most soluble salts we know, but one of these rare exceptions is the bicarbonate, which is considerably less soluble than either the carbonate or the chloride of sodium. This difference of solubility therefore just supplies the opportunity which is needed to make the foregoing reaction available as a means of producing carbonate from chloride of sodium. If excess of carbonic acid gas is passed into the mixed solution, bicarbonate of sodium is formed, and if the original solution of salt has been sufficiently strong, the part of the bicarbonate separates as a crystalline powder. By passing into the solution ammonia and carbonic acid in considerable excess so that the upper equilibrium point of the mixed salts is reached, a large proportion of the chloride is converted into bicarbonate and separated. It is only necessary to drain the separated bicarbonate and to wash it slightly with a saturated solution of bicarbonate in order to obtain a very pure product. This bicarbonate parts with its excess of carbonic acid when it is gently heated, and leaves a soda ash of exceptional purity and strength.

The Leblanc process is a remarkably fine piece of strategy, but beside the delicate finesse of the ammonia soda process its methods are made to appear almost brutal!

The raw materials of the ammonia process are salt, ammonia, and carbonic acid. The salt as it occurs in concentrated brine is just in the right condition for the process, but the ammonia and carbonic acid have to be imported into the works or prepared there. The making and purification of carbonic acid do not present any difficulty. Part of what is required is brought in by the ammonia which is imported from the gas works in the form of a concentrated solution of carbonate or bicarbonate. Another part is kept in circulation in the process, and the remainder is made by heating limestone and coke. Ammonia is relatively a very expensive substance. While the selling price of the soda ash is under £5 per ton, the price of ammonia is about £55, or 11 times as much. It is obvious, therefore, that if any considerable quantity of ammonia were lost or destroyed in the course of the process, its cost would be excessive. The commercial success of the process has largely depended on the recognition of this fact, and in the provision of such perfect apparatus and methods as have reduced the loss of ammonia to a very trifling amount.

The only waste product of the process is the solution of chloride of calcium containing some undecomposed salt, which is left after the separation of the bicarbonate of sodium and the driving out by the action of lime and heat of the ammonia with which the brine had been saturated. The ammonia which is in combination with carbonic acid is driven out by heat; milk of lime is then added to the solution of chloride of ammonium which remains, the lime combines with the chlorine forming chloride of calcium, and the ammonia is driven off by steaming, and is condensed and returned again to take its place in the first stage of the process. The chlorine of the salt makes its final appearance in the chloride of calcium liquor which is run away as valueless. In this process no hurtful gases are evolved, and no unsavoury residue is left behind to pollute earth, air or water. The high value of the ammonia which is used as a re-agent ensures that every operation be carried out in strictly gas-tight vessels.

So long as the Leblanc process was the only source of chlorine for the making of bleaching powder it was looked upon as a certain disadvantage of the ammonia soda process that in it the chlorine could not economically be made available for this purpose. Great efforts were therefore made to devise a process by which this might be effected. While no real success attended these efforts, it is probable that they would have been pushed still further had it not been that the direct separation of salt into its elements by electrolysis on a commercial scale became an accomplished fact while these attempts to find a new process were being made.

It has already been pointed out that when salts are dissolved in water a certain small proportion of their molecules became dissociated into their ions, so that in a solution of chloride of sodium there are free ions of chlorine and sodium as well as molecules of the salt itself. When a current of electricity is passed through such a solution, the ionization of the molecules becomes more general, and the different ions carrying charges of opposite electricities, and are impelled each to their respective poles, the anions to the anode, and the cations to the cathode. In the solution of chloride of sodium the chlorine ions go to the anode, and the sodium to the cathode.

For the discovery of the laws of electrolysis we are indebted to Faraday. In both the preceding lectures of this series the name of Faraday has been associated with the foundations of the subjects treated of. In this respect the present lecture can be no exception, for in Faraday we recognise the great master whose powers of research and whose marvellous intuition enabled him to give to the world, seventy years ago, a complete and beautiful theory of electro-chemical equivalence, or, as he himself called it, "*A doctrine of electro-chemical action.*"

But even Faraday's wonderful insight did not enable him to foresee that fifty years later his doctrine of electro-chemical action would find extensive industrial application through the fruition of his own discoveries in magnetism and electricity, as these have been developed in the modern dynamo-electric generator.

It is sufficiently obvious that the beautiful process of electrolysis must have remained for ever in the scientific laboratory had it not been for the possibility of generating electric current in large quantity, and at a cost which enables it to replace energy in the form of heat.

When the electrolysis of a solution of salt is carried out in a simple cell in which the anode and cathode are separated only by the solution, the work done by the current in separating the chlorine and sodium, and conveying the ions to their respective electrodes is largely undone by the re-combination of these elements which takes place in the solution outside of the influence of the current. To avoid this back action two methods have been used. In the first the cell is divided into two compartments by a porous diaphragm, which is permeable by the charged ions, but does not allow the uncharged ions to pass through and mix. In the anode compartment chlorine is given off as a gas. In the cathode compartment the sodium ions which are received on the electrode immediately decompose the surrounding water molecules, forming $NaOH$ or caustic soda, which remains in solution, and hydrogen which is given off as a gas. By the second method, which was devised by Castner, the cell is divided into two compartments by a diaphragm which reaches nearly, but not quite, to the bottom. In this case the diaphragm is not permeable. The cell is mounted so that it can be slightly tilted from side to side. By this tilting the floor of the cell is inclined now to one side, now to the other. On the floor of the cell sufficient mercury is placed to completely cover it, and to reach to the lower edge of the diaphragm. When the floor at the anode side of the cell is depressed, the great bulk of the mercury flows into it and forms the cathode. The current passes through the brine and decomposes it, carrying the chlorine ions to the anode, where they unite and come off as gas. The sodium ions go to the cathode and there unite with the mercury forming sodium amalgam. When the cell is again tilted the great body of mercury with the sodium amalgam passes under the diaphragm into the other compartment, which is kept supplied with pure water. The sodium in mercury at once decomposes the water and forms caustic soda, while the hydrogen of the water escapes to the surface as a gas. In this way the chlorine and the caustic soda are kept completely apart, the chlorine being practically free from hydrogen, and the caustic soda solution being free from chlorine. The chlorine gas is drawn off through earthenware pipes to the bleach chambers, where it is absorbed by slaked lime forming bleaching powder. The solution of caustic soda is drawn off continuously, its place being supplied by a corresponding quantity of fresh water. A small stream of strong brine is run into the anode compartment, and a corresponding quantity of weakened brine is run out to be strengthened by the solution in it of a fresh quantity of salt.

It will be noticed that the sodium is obtained as caustic soda, not as carbonate. As caustic soda is a much more valuable product than carbonate, this is to the advantage of the process.

In the electrolytic process we have arrived at the simplest possible way of separating salt into its elements and obtaining the sodium as alkali. The only raw material is the salt or brine, and there are absolutely no waste products. In addition to the raw material it is necessary to supply, in the form of electric current, the energy required to break up the salt into its elements. Theoretically, this is exactly equivalent to the energy of combination of these elements. In practice, however, there is a certain loss of energy, but the energy efficiency of the electrolytic process is high as compared with that of the two other processes. Against this efficiency must be placed the fact that the energy has to be supplied in the more expensive form of electric current, while in the others it is supplied in the cheaper form of heat generated by the combustion of coal.

I believe that this is the only point on which there can at first have been any doubt as to the all round superiority of the electrolytic process, but even this is now met by recent developments in the cheap production of electricity. By the use of the most improved steam engines, and still further by the adoption of gas engines, the cost of electrical energy in England has been reduced to a point at which most of the processes of industrial electro-chemistry can be worked in Great Britain as advantageously as in countries like France or Switzerland, where cheap water power has been supposed to give such undertakings a great initial advantage. From my own experience of electro-chemical industry in Germany, France, England, and America, I can say that the British electro-chemical manufacturers have no cause to be ashamed of the position they have taken in this industry, nor need they be uneasy as to the foreign competition which may still be in store for them. In Germany and America there always appears to be a greater disposition to launch into over production at unremunerative rates than is found in Great Britain, but we must not suppose that this necessarily means that the foreign producers are able to manufacture more cheaply than we are, but only that they are willing to make heavy sacrifices in order to secure a share of our markets.

In the electrolytic process we are again brought face to face with the same disadvantage as that mentioned in connection with the Leblanc process, namely, that for every equivalent of soda ash produced an equivalent of chlorine must be disposed of. The output of alkali by the Leblanc process was already limited by this consideration, obviously therefore the advent of another process which produced chlorine of necessity was calculated to aggravate an already difficult position. In Germany and France, owing to certain special conditions which exist there, the electrolytic processes have almost completely displaced the Leblanc in the potash as well as in the soda industry. This has resulted in a greatly increased production of bleaching powder, as the electrolytic output of chlorine from a given weight of salt is larger than the Leblanc. In America also new electrolytic works have been started, and under a steadily increasing home production the imports of bleaching powder from Europe have necessarily decreased. The effects of this steadily increasing over-production culminated about eighteen months ago, and the price of bleaching powder dropped from £6 down to £3 per ton. On the British output of about 100,000 this meant a loss of profit of about £300,000. What proportion of this represents an actual loss to the manufacturers is only known to the individual sufferers. There is no disguising the fact that the Leblanc and the electrolytic processes are deadly rivals, and the duel between them will sooner or later have to be fought out *a outrance.* The prize which must be fought for is *the outlet for chlorine*, and if the would-be inventors could only be brought to realise that *this* is the crux of the situation they might perhaps be influenced to divert their attention from the devising of new processes of chlorine manufacture which are not needed, to the finding of profitable uses for the chlorine which is already being produced largely in excess of the world's requirements.

During a fairly long association with processes and inventions, nothing has struck me more than the enormous waste of time and skill which results from inventors *following in the wake* of the requirements of the time rather than *leading in the forefront.* If the would-be inventor would only take a little trouble to find out what the world wants, or is likely soon to want, and would concentrate his energies on the meeting of these wants, the ground would be cleared of some at least of the worthless rubbish which encumbers the patent office and impairs its usefulness.

The development of industrial electro-chemistry must always be associated with the name of H. Y. Castner, whose processes for the electrolysis of salt I have described. Mr Castner entered the field of applied chemistry in 1885 as the inventor of a chemical process for making metallic sodium. At that time aluminium was made by the action of sodium on chloride of aluminium. Believing very strongly in the future of the metal aluminium, Castner threw himself enthusiastically into the solution of the problem of its cheaper production ; his sodium process was therefore regarded as a step towards that end. He came to England in 1886, and with the help of various influential persons, he established works at Oldbury for the manufacture of sodium and aluminium. Sodium, which had previously been one of the rare metals was here produced at a cost of 8s. or 7s. a lb., but even at this comparatively low price its use was at first practically restricted to the making of aluminium and its alloys. The Aluminium Company of Oldbury was practically the pioneer of this industry, and unfortunately it was doomed to share the fate of many another pioneer: one day it found itself outstripped in the race in which it had hitherto set the pace ! C. M. Hall, another American chemist, had discovered that aluminium could be made directly from its ores by electrolysing these in a bath of molten cryolite. This was a severe blow to Mr Castner and his associates, but the true inventor never knows when he is beaten ! In 1891 he produced his process for the production of metallic sodium by the electrolysis of molten caustic. By this process the cost of production was reduced from 8s. per lb., to about 1s. Even at this low cost the sodium process of making aluminium could not compete with the electrolytic and other uses had to be found for metallic sodium. Aluminium is now made in Scotland at Foyers, by the British Aluminium Company, as well as at Neuhausen, and at Niagara. Sodium is made in England, at Weston Point, by the Castner Kneller Company; at Rheinfelden by the Electro-chemische Fabrik Natrum; at Clavaux in France by la Société d'Electro-Chemie; and at Niagara by the Electro-Chemical Company of Niagara. It is used as a raw material in the making of artificial indigo, antipyrin and cyanide for gold extraction. The greater part of the sodium produced in England is now brought to Glasgow where it is converted into cyanide of sodium by the Cassel Gold Extracting Company. Twenty years ago metallic sodium was exhibited in small specimens as one of the rare metals, to-day it is produced at the rate of several thousands of tons per annum at a price which places it among the ordinary metals of commerce, zinc, tin, or copper. With metallic sodium as with chlorine what is most wanted at present is not new processes for its manufacture, but new outlets for the immense output which the existing works are capable of producing.

While engaged in working out his sodium process, Castner found that it was of great importance that the caustic soda used in sodium making should be of the utmost purity. The best caustic which could be obtained by the Leblanc process was still too impure, he therefore devised his electrolytic cell for the production of caustic soda and chorine from brine. This process was worked out at Oldbury, and was then transferred to the works of the Castner Kellner Company at Weston Point, where it has been in successful use ever since. I think I am right in saying that this was the first economically successful application of electrolysis to the manufacture of alkali and chlorine.

Reference has been made to the manufacture of cyanides of potassium and sodium for gold extraction. I need not remind you that the cyanide process for the extraction of gold from its ores was the invention of Mr J. S. Macarthur and the Drs James and William Forrest of this city. Prior to the introduction of this process cyanide of potassium was used in the arts in comparatively small quantities. With the advent of the gold extracting process a new and very much larger demand sprang up. This was at first met by the well known process of Liebig, in which ferrocyanide of potassium is melted with carbonate of sodium and charcoal. In Germany Dr Siepermann had for some years been working out a process for the synthesis of cyanide, while in Scotland I also had been working at the same problem. In both of these processes the raw materials employed were carbonate of potassium, charcoal, and ammonia; in both a fairly high temperature was necessary for the reaction. Beyond this point all similarity in the processes ceased. Siepermann, like all previous experimenters, used charcoal in such large excess that his mixture remained infusible throughout the process; the cyanide being finally recovered by dissolving out the soluble salt with water. In my process the proportions of the materials were so adjusted that the mixture throughout was a fluid one, and only so much charcoal was used as would leave a small excess at the end of the operation. One result of this was that the final product was a molten cyanide of high strength, which only needed to be filtered from the small excess of insoluble matter which it contained and cast in moulds in order to give a finished product in massive crystalline cakes of pure white cyanide. The technical difficulties which were encountered in the practical working of this process were very serious, indeed, they have been regarded by various well informed chemists in England and Germany as quite insurmountable, and the process was dismissed by these writers as entirely impracticable. Strange to say, notwithstanding these emphatic opinions, this process which was started on a commercial scale in 1892, has been continuously worked ever since, and has produced a considerably larger proportion of the world's requirements of cyanide than any other process. Coming at the early time it did, this process was the means of retaining for Scotland a commanding position in the cyanide production of the world, a position which would otherwise undoubtedly have fallen to Germany.

For the patient and courageous development of this process through its many difficulties, great credit is due to my colleague Mr George Christison who has been associated with the process from its early beginnings on a commercial scale.

Before leaving the alkali and its allied industries, I must refer somewhat briefly to the manufacture of sulphuric acid, the essential and most active agent in alkali making by the Leblanc process.

Sulphuric acid or "Oil of Vitriol" was commercially known considerably before the beginning of the last century. Mr Oscar Guttmann has described an interesting manuscript in his possession which was evidently the note-book of a chemist, W. E. Sheffield, who lived in Birmingham from 1771 till 1790. In this manuscript there is a complete description of an installation for the manufacture of sulphuric acid. The leaden chambers or "lead houses" as they were called in this description, were 8½ feet high, 6 feet long and 4½ feet deep. The sulphur mixed with nitre was placed on a dish in the centre of the chamber and was set fire to by a red hot rod. A layer of water on the bottom of the chamber absorbed the sulphuric acid as it condensed from the atmosphere of the chamber.

This primative apparatus developed into the larger and more complicated form as we now find it in the modern chemical works, consisting of sulphur burners, chambers and condensing towers.

An atom of sulphur, when it is burned in air, takes up two atoms of oxygen forming sulphurous or sulphur dioxide.

The further oxidation of the dioxide into the trioxide or sulphuric anhydride and the union of this substance with the elements of water to form sulphuric acid is carried out in large chambers in which sulphur dioxide, steam, air and nitric acid are intermingled and allowed to react together. It will be observed that the function of the nitric acid is to act as a conveyor of oxygen from the air to the sulphur dioxide. The nitric radicle swings between two states of oxidation ; in the lower of these states it picks up an atom of oxygen from the air, and swings over into the higher state, here it meets a molecule of sulphur dioxide to which it gives up an atom of oxygen and swings back into the lower state. There is therefore no actual consumption of nitric acid in the process itself, the loss which takes place in practice being due to the carrying away of nitrous gases from the chambers in solution in the sulphuric acid and with the waste gases leaving at the exit from the chambers.

No attempt was made to arrest these loses till 1827, when Gay Lussac proposed to absorb the nitrous compounds from the exit gases by passing these gases over surfaces wetted with fresh sulphuric acid, this acid being subsequently heated to drive out the nitrous gases for re-use in the chambers. The adoption of this suggestion only took place twenty years after it was made, that is to say, after Mr John Glover had proposed a plan by which the sensible heat of the sulphur gases as they leave the burners, might be used for the concentration of the weak acid from the chambers, by introducing a scrubbing tower between the burners and the lead chambers. The hot burner gases were led in at the bottom of the tower, and from the top they passed into the first lead chamber. The tower was loosely packed with flints. The weak acid from the chambers was showered over the top surface of the flint packing and trickling over the great surface presented by the flints, was exposed in thin layers to the up-coming current of hot gases from the burners. This exposure had a twofold effect; it evaporated the excess of water contained in the acid conveying it back into the chambers where it replaced a certain quantity of fresh steam which would otherwise have had to be supplied from steam boilers, and at the same time the exposure to the hot gases drove out the nitrous gases which were in solution in the weak acid and conveyed them also back to the chamber where they were required. By introducing the Glover tower at the entrance to the chambers and the Gay Lussac at the exit, the system of recovery of nitrous fumes was made complete.

The Gay Lussac tower is of somewhat similar construction. The gases from the chambers are led in at the bottom and off at the top. The object now being the reverse of that of the Glover tower, namely, to absorb the nitrous gases, a fairly concentrated acid is run down through the tower, a sufficient quantity being used to entirely free the gases of their nitrous contents. The acid from the bottom of the Gay Lussac is taken to the top of the Glover tower, and is passed down together with the chamber acid, giving off its nitrous contents by this way.

The benefit from establishing a closed circuit of this kind for the nitrous gases is very obvious, and its introduction was at once justified by the great saving of nitric acid which took place.

Mr Gossage has stated that up till 1869 there were neither Glover nor Gay Lussac towers in the Lancashire district. Seeing that the Gay Lussac had been invented in 1827, or 42 years before, and the Glover in 1859, ten years before, one is almost justified in classing the sulphuric makers of that date as of those who have had science "thrust upon them!"

Mr John Glover did not patent his tower, and yet the benefits he has conferred on the chemical industry of the country would need to be reckoned in hundreds of thousands of pounds sterling, if not in millions.

In recognition of his great services to the chemical manufacture of the country, the Council of the Society of Chemical Industry made the first award of its gold medal to Mr John Glover, in July, 1896.

Towards the end of the century a very interesting departure was made in the manufacture of sulphuric acid by a new method.

I have already pointed out that by burning an atom of sulphur in air it is only possible to get it to take up two atoms of oxygen, the product being sulphur dioxide. In the chamber process the additional atom of oxygen is added on by the agency of nitric acid which acts as a carrier of oxygen from the air to the sulphur dioxide.

It had for long been known that the direct combination of oxygen with sulphur dioxide can be brought about by passing the mixed gases over heated platinum. So early as 1831 attempts were made to introduce this as a substitute for the nitric acid process, but without any practical success. In 1878, Winkler patented the use of various "contact substances" of high activity for this purpose, and in the following years Squire and Messel patented a process for the manufacture of sulphuric anhydride by a contact process.

For many years the practical results of the various proposed processes were kept secret, and it was somewhat of a surprise to chemical manufacturers at large, when in his Hurter Lecture in 1899, Professor Lunge brought to their notice the startling intelligence that some of the great colour manufacturers in Germany were already manufacturing ordinary oil of vitriol by the contact process at a cost which compared favourably with that of the chamber process. A few weeks ago a paper was read by Mr Oscar Guttmann, before the Society of Chemical Industry, on the comparison of the costs by the two processes, (S.C.I.J., vol. xxii., p. 1331.) Mr Guttmann makes a careful analysis of the various improvements which have been, and which are now being effected in the chamber process, and shows the effect of these on the cost of manufacture. His calculations are summed up in a very useful table, from which we find that the cost of one ton of 98 per cent. acid, made by the most improved form of the old process is £1 13s. 3d., and by the contact process, £1 18s. to £2.

The study of the contact process opens up a variety of most interesting questions on the borderland between physics and chemistry, but I fear that this is hardly a suitable occasion for their discussion.

Before leaving the subject of sulphuric acid, I ought, perhaps, to remind you of the widespread importance of the industry. Probably the largest consumption of vitriol is for the making of superphosphated manure by the dissolving of bones or mineral phosphates.

We have already seen the important part which it plays in the alkali industry. Nearer home we find it extensively used in the shale oil industry for the purification of paraffin oils and for the making of sulphate of ammonia. So extensive is its use for these purposes that the larger oil works manufacture it for themselves.

The sulphate of ammonia industry uses not less than 250,000 tons per annum. For the making of nitric acid, in dyeing and colour making, in explosives making, and in a multitude of miscellaneous industries sulphuric acid is a necessity. It is obvious that the great reduction which has taken place in the cost of its manufacture has meant an enormous saving to the country. In 1830 the price at Liverpool was 2d. per lb., or £18 13s. 4d. per ton, in 1840 it was 1½d. per lb. or £14 per ton, in 1878 it had fallen to £4 per ton, to-day it is about £3, and Mr Guttmann tells us that it can be made for less than £2, or less than one ninth of its value seventy-four years ago.

In the prices of alkali and bleaching powder similar reductions have been made. The price of soda ash in 1830 was £16 10s. per ton, to-day it is £4 5s., or rather over one-fourth. The price of bleaching powder in 1840 was £19 per ton, to-day it is £3 10s. or not much over one-sixth.

The paper-making, bleaching, and soap-making industries have all profited by these reductions in price.

I will ask you now to turn with me to a brief review of an industry of a very different character, but one in which chemistry has played a most important part. I refer to the Beetroot Sugar industry.

The beetroot sugar industry supplies a very remarkable illustration of what may be accomplished by scientific organisation and development. Some of our fiscal friends would probably say that it is a monument to the policy of protection; but in my opinion no question of fiscal policy can detract from the magnificence of the scientific and industrial achievement which it presents to us to-day.

In its interests the agriculturist has carefully selected and bred the most suitable plants, and the chemist has determined the conditions of soil and manuring which will enable the plant to produce the highest percentage of sugar in the roots. This percentage has gradually been raised from 8 or 10 up to 16 or 18 per cent., that is to say, roots are now grown which yield sugar equal to about one-sixth of their weight.

On the engineering side the developments have been no less important. The extraction of the juice from the pulped roots, its purification, and its evaporation and crystallisation are all carried on in apparatus of the best design. The filterpress, the multiple-effect evaporator, and the centrifugal separator are some of the types of apparatus whose development we owe to this industry.

In the juice expressed from the pulped roots is contained all the soluble constituents of the plant. Cultivation and proper nourishment have raised the proportion of sugar to an extremely high point, but the juice necessarily contains all the salts of potash and soda which have been taken up from the soil, as well as the various soluble organic substances which have taken part in the life and growth of the plant. Among these are various substances rich in nitrogen, which are probably the most unpleasant impurities which accompany the sugar, and render its perfect refining rather a troublesome problem. These nitrogenous substances give an unpleasant and unpalatable character to the molasses which in this respect is a very different product from the molasses from cane juice.

The object of refining is to obtain as much as possible of the sugar of the beet in a good merchantable form, clean, crystalline and free from unpleasant taste or smell. After certain processes of clarification the juice is evaporated to the crystallising point in vacuum pans, and successive crops of crystals are taken from it. These crystals are separated from adhering syrup and washed with water or clean syrup.

When the juice has yielded up its last crop of crystals there is left a thick viscid, highly coloured and strongly smelling liquid which still contains about 50 per cent. of sugar, 20 per cent. of other organic matters, 10 per cent. of salts, and 20 per cent. of water. This is beetroot molasses, a very different product from cane sugar molasses. I doubt if even Mrs Squeers would have had the hardihood to administer beetroot molasses to poor Smike!

The first object of the refiner is to recover as much as possible of the sugar of the molasses in marketable form. The successful carrying out of molasses refining involves so many chemical processes and so elaborate an installation of apparatus that it is the practice in Germany to have central molasses refineries which draw their supplies of molasses from the sugar works of a whole district.

The primary operation of sugar extraction from the fresh beets is necessarily carried on at the time of the harvest. Like wine-making it is therefore confined to one comparatively short season. But this restriction need not apply to molasses refining as the raw material can quite conveniently be collected and stored in large tanks. In this way the refineries are enabled to work continuously.

To obtain the sugar from molasses advantage is taken of the fact that sugar combines with the alkaline earths to form feeble salts which crystallise in definite well-formed crystals. The crystals of sucrate obtained in this way are drained from the adhering molasses and are washed till they are free from the highly coloured and evil-smelling material. They are then mixed with water and are decomposed either by carbonic acid or by a simple change of temperature when the alkaline earth separates from the sugar as an insoluble precipitate which is filtered and washed, and further prepared by calcining or otherwise for the treatment of a fresh batch of molasses. The clean solution of sugar which has been filtered from the alkaline earth is evaporated and crystallised in the usual way. The brown thick liquid from which the crystals of sucrate have been separated now represents the quintessence of the impurity of the original beet juice. It contains the potash and other salts together with the organic constituents other than sugar. This residual mixture is called "schlempe." As the nitrogenous constituents are all concentrated in the schlempe the percentage of nitrogen it contains is very high.

Five years ago, or even less, it was the universal practice to burn off the organic matter of the schlempe in furnaces so as to obtain the potash salts in the form of a coke or residue which is known as "schlempe kohle." In five out of the six large molasses refineries in Germany this is still the practice, but in the sixth which is situated at Dessau, a beautiful supplementary process for the utilisation of the nitrogen of the schlempe has been in use for about four or five years. This process is the invention of Dr Bueb of Dessau, whose name has become well known through his association with various gas purification processes. The details of the process have been worked out with admirable skill and patience by the inventor in association with Mr Vessator, the managing director of the molasses refinery. The disposal of the organic matter of the schlempe is now accomplished without creating any nuisance, while the nitrogen it contains has been made to yield a handsome profit.

By the older process of burning, the nitrogen along with the greater part of the hydrogen and carbon was dissipated as a cloud of black evil-smelling smoke, which was a serious nuisance to the neighbourhood.

In the new process the schlempe is run into iron retorts in which the volatile portions are distilled off, leaving a residue of carbon mixed with potash salts. The recovery of the potash salts is accomplished as formerly by lixiviating the residue.

The vapours and gases which leave the retorts are led through chambers filled with brick chequer work which is maintained at a red heat. By contact with the surface of the red hot bricks the complex vapours are decomposed into hydrocarbon gases, ammonia and hydrocyanic acid. These gases are led through suitable scrubbing arrangements for removal of ammonia and hydrocyanic acid. The former is converted into sulphate of ammonia, and the latter into cyanide or ferrocyanide of sodium. The gases after scrubbing are burned as fuel gas for the heating of the retort and the decomposing chambers.

From this brief sketch it will be seen that the beetroot sugar industry is almost an ideal cycle in which the processes of nature take their place in due sequence with the artificial processes of science, the products of these, potash salts and ammonia, being returned to the soil to take their place again in the cycle of operation. The pulp of the beetroots, after the removal of the juice, is used for feeding stock. Sugar is a pure carbohydrate, that is to say it consists of carbon combined with the elements of water, oxygen, and hydrogen in the same proportions as they occur in water. The sugar therefore carries away nothing from the soil as it is formed in the plant by the union of the carbonic acid of the air with water derived from air and soil. During the process of refining the products of the soil itself and those of the living cells of the plant are removed as impurities as salts and nitrogenous substances. If the whole of the nitrogen of the schlempe were recovered as ammonia and returned to the soil, and if the potash and other salts were also so returned, the cycle would be complete. In actual fact this is not done, for the nitrogen has a higher value as hydrocyanic acid than it would have as a manure, while the same is the case with the potash salts in the schlempe kohle.

It is difficult for us to realise the enormous proportions to which the beetroot sugar industry has grown practically within one generation. The total European production of beetroot sugar in 1903-4 is estimated at 5,286,855 tons. In this production Germany leads with an output of 1,803,160 tons. Taking the molasses as equal to 30 per cent. of this we have 540,000 tons which has to be dealt with in the refineries if no allowance is made for what may be diverted into other channels. From this fund of raw material each refinery might produce 700 tons of cyanide of potassium and a like amount of sulphate of ammonia. This matter will be referred to again in another connection.

So long as the Continental nations continue to supply Great Britain with sugar at or below its cost price we can hardly expect the capitalist and the manufacturer to devote money and energy to the organisation of the beetroot sugar industry in England, but so far as I know, there is no reason why the sugar beet should not be successfully grown here. Given an adequate supply of the raw material there is no single part of the subsequent operations which could not be as well done here as in Germany or France.

The advances made during the nineteenth century were due to general as well as special causes. To the former belong the greater freedom of transport by sea and land, and the replacement of hand labour by steam engines and machines. These, together with the adoption of free trade, affected every industry almost equally. Among the special causes may be mentioned the rapidly growing knowledge of chemical, physical, and mechanical laws, and their application to the problems of industry. The recent growth of the electrical and electro-chemical industries is one illustration of this, but many others might be cited. During the past thirty years the more direct application of a special kind of engineering skill to the design of apparatus for chemical operations has been a most important factor. In many cases chemical processes have had to wait till a suitable apparatus could be designed and made. This was the case with the ammonia soda process, and with most of the electrolytic processes.

The organisation of the scientific side of the industry has also contributed to the advance. Prior to 1881 there was no such organisation worthy of the name, but in that year the society of chemical industry was founded under the presidency of Sir Henry Roscoe. At the first meeting of the society it was stated that 297 members had joined. At the date of the last annual meeting the membership had reached 3,950. Of these about one fourth belong to the New York section. In addition to seven sections in Great Britain, the society has sections in Canada, New York, and Sydney. Although there are no European sections outside of Great Britain, there are a great many members in Germany and France, as well as in other European countries. The society has numbered many distinguished men among its presidents.

Since the society of chemical industry was founded, various societies of specialists have been successfully started. Among these the most recent is the Faraday Society, of which Dr J. W. Swan is the first president.

Every three years an International Congress on applied chemistry is held in one of the great capitals. Last summer the Congress sat at Berlin. Over 2,000 chemists from all parts of the world met, and much useful work was done by the eleven sections into which the Congress was divided.

The German government showed its sense of the importance of this gathering by placing the whole of the houses of parliament at the disposal of the Congress for the week during which the sittings took place.

The real significance of all this is as yet only appreciated by those who are more or less in touch with the industry of to-day.

Not only the international character of the industry, but its close touch with the advances in the great branches of pure science, physics, chemistry and biology make the position of its leaders a more and more exacting one, while it makes it the more imperative that the equipment of its future leaders, the young men who are now passing through our universities and colleges, should be the most complete possible. Above all, it is vitally important that the coming leaders should have their mental equipment cast in a big broad mould.

The other day Mr Chamberlain urged the financiers of the city of London "to think imperially." That kind of thinking may or may not be the most suitable for protectionist financiers, but

I would say to all my fellow workers in industry, let us think scientifically and internationally, for sooner or later we shall be called upon to measure ourselves, not against any narrow section of our fellow men, but against the whole world.

The Clear Facts of the Commercial Situation, and the Divergent Conclusions drawn from them. By W. J. ASHLEY, M.A., Professor of Commerce and Public Finance in the University of Birmingham.

[Read before the Economic Science Section, 23rd December, 1903.]

AMONG the most unfortunate—though perhaps among the inevitable—features of the present controversy, is the confusion between *facts* and *opinions*. Each side produces its statistics, which are at once pounced upon by the journalists and experts of the other side, and damaged as much as possible; until it is coming to be the general impression that *no* figures are to be trusted, that *all* statistics can be manipulated to suit a purpose, and that the ordinary man cannot get at the truth. This is, as I have said, unfortunate, and that in more ways than one; and especially for this reason—that it wastes time over preliminaries which were better employed over the ultimate issues; and, indeed, that it tends to obscure the distinction between preliminaries and ultimate issues—between the facts of the situation and the divergent conclusions which, so long as people differ in their general outlook on life, are sure to be drawn from them.

But surely it is to think very meanly of "the resources of civilisation," to suppose that the main external facts of our commercial position cannot be ascertained and lifted out of the range of party controversy. And it is to that task that I desire to make a contribution to-night. Fortunately I am able to refer to a source of information which all parties recognise as a very high authority—the celebrated fiscal blue book which was issued last September. Its full title is *Memoranda, Statistical Tables and Charts prepared in the Board of Trade, with reference to various matters bearing on British and Foreign Trade and Industrial Conditions:* it is most conveniently ordered under the name *1903, Cd. 1761;* and it costs 3s. 6d. I am thus particular because it ought to be more widely circulated than it is, and I would suggest that it would make a useful New Year's present! For the sake of brevity I shall refer to it in future as the *Fiscal Blue Book.* I do not regard it as giving us by any means all the help that the Board of Trade should be able to furnish us with in such a crisis. Its limitations are due to the fact that the Statistical Department of the Board of Trade has never yet conceived it to be its duty to watch the development of the several industries and trades of Great Britain and foreign countries as living wholes—as organisms (to use a convenient phrase) with an internal movement as well as external relations. It has contented itself with collecting certain statistical returns, and tabulating them in various ways; and when as now, it is suddenly called upon to report on such questions as dumping, it has to hastily look around and snatch up what fragments of information it can find in readily accessible sources. The Fiscal Blue Book illustrates the limitations of its source—some necessary in a government office, some in my judgment not necessary—in almost all its parts. Still it does not profess to be more than a series of "memoranda" on particular points; and a firm grasp of the principal data it furnishes ought to be regarded as "the beginning of wisdom" in the present discussion.

It is the purely economic side of the matter which I assume the Economic Section of the Glasgow Philosophical Society desires to discuss, and it is to that that I shall entirely address myself in the body of this paper. But, before doing so, I will ask you to allow me a word of personal explanation—and this is that in my eyes the imperial and, if you like, sentimental aspect of the problem is quite as important as the purely economic. I should urge, indeed, that the two aspects cannot be separated; and that a real and effective Empire is our most probable chance of permanent economic well-being in these islands. But even if this were not so; even if a preferential policy would leave us in its total result just where we are economically, and not a penny better off, I still think it most desirable. Of course if it could be shown that it would impose upon these islands an absolutely crushing burden—that it would amount to something like national suicide—no imperial considerations ought to weigh with us. Existence comes even before Empire. But I don't think this can be shown. I would go further and say, that if a preferential policy did involve some slight burden, it would be better for our manhood, for our character, that we should bear it rather than lose our empire, just as we all feel it is nobler for a nation to bear the burden of an army of defence than to live in unglorious comfort under a foreign yoke.

Now I have not the slightest doubt that if things go on as they are the great self-governing colonies will drift entirely away from the mother country in a few decades; and a preferential policy appeals to me, not indeed as a certain, but as the only likely and practicable way of binding the several parts of the empire together. You will bear with me for simply putting these before you as personal convictions without a shred of argument. My excuse is that our time this evening is so short. Such assertions will be met by some with the contention that the imperial tie is safe enough, and that we can trust to the forces of sentiment already at work without devising economic links. All I have time to say is that such is not my conclusion, from my observation of Canadian conditions and my study of Australian affairs. Or it may be granted that fresh ties are necessary, but that they may be found in other directions. Throughout this paper I shall avoid any reference to individuals; so that I will only say here that though this is the hope of statesmen, both Liberal and Conservative, for whom I have a high respect, I am unable to see any likelihood of its realisation. There are, of course, those who recognise the probability of a splitting-up of the Empire, and say it will be a good thing: that the weary Titan has too long stumbled beneath the too vast orb of his fate: that we should give up the vain hope of being more than two small islands isolated in the midst of great Empires, and content ourselves with living on the glorious memories of the past. I'm afraid we should not comfortably include the memories of Chatham and Clive among them; but we could concentrate on Wallace and Burns. I do not get indignant with such people; some of them are among the moral salt of the earth; but I simply do not share their views. And, finally, there are those that say that, whether we can be content with it or not, the Empire is bound to break up, and no tariff schemes will help us. Well I do not profess to have an unruffled confidence in the efficacy of the plan; but I believe it is the only chance open to us, and that we ought to make the best of it. I have already got to "finally," but perhaps I ought to refer to those who think that preferential negotiations will in themselves alienate the Colonies. Certainly there is some danger, but if they do not negotiate with the mother country, they will inevitably, after a while, begin to negotiate with foreign countries.

There, then, is my imperial confession of faith. I trust you will not think it has been unfair to thrust it upon you, though there will not be time properly to discuss it. It may save us from the unreality of arguing one side of the subject, while the other side is at the back of all our minds.

I. To come now to the Blue Book. Look *first* at the *Memorandum on the Excess of Imports into the United Kingdom.* It reckons this for the last ten years as about 161 millions. We cannot have paid for these in "golden sovereigns," for *(a)* to do so would have deprived us of our whole stock of such interesting coins, and *(b)* we know the amount of bullion and specie that leaves the country (except in the pockets of travellers), and we know that for those ten years there has been an excess of import of bullion and specie over export to the extent of some 6 million pounds annually; and this is already reckoned in the 161 above mentioned. Everyone who has given any serious attention to the matter is aware that the excess of imports is a matter of long standing; and economic students have for years accepted Sir Robert Giffen's explanation that the excess corresponds to (1) the earnings of our shipping—what he calls "an invisible export," and (2) the earnings of our investments abroad. The Board of Trade Memorandum, bringing Giffen's estimates up to date, accounts for the 160 millions by assigning 90 to freight, etc., and some 70 millions to investments. Why should not all sides accept these estimates as substantially accurate? But now what are we to think of the situation thus presented? That is really the question. There are some who are so re-assured by this exposure of the golden sovereigns fallacy that they seem to think it is sufficient to echo this memorandum and leave the problem just there. But let us observe that the "excess of imports" is growing. Sir Robert Giffen in 1882 took the figure 120 millions, not 160, to operate with, since 120 was the average between 1875 and 1880. But the average between '60 and '74 had been only half that, some 60 millions; and between 1854 and 1859, not much more than half that, viz., some 34 millions. That is, to pay for our necessary imports of food and raw materials, Great Britain is becoming increasingly dependent on its investments abroad and on the earnings of its shipping. Is that a wholesome and satisfactory state of things? It was very largely the condition of Holland in the first half of the 18th century, when it still did the larger part of the carrying trade of Europe, and had more money invested abroad than any other country. And as to the carrying trade in particular, there are not wanting signs that the British hold upon that is already weakening.[1]

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[1] Some of these are collected in the 2nd edition of my book, *The Tariff Problem*, pp. 215-227.

II. Turn now to *visible exports.* These are given in figures, and then set forth to the eye in one of the many Blue Book charts, (Series A, III). From this it appears that between 1872 and 1898, whatever may be said of subsequent years, the amount of total exports, and also of manufactures—well, how shall I say it? Perhaps one ought not to say "were stationary" or "stagnating"—but cannot one say "showed but a slight increase," or "maintained with greatly increasing difficulty their upward tendency?" Is it worth while quarrelling as to how we shall describe this line on the chart; there is the line itself for anyone to see. True, 1872 was an exceptional year. Indeed, no comparison of particular years is any use. But the same is true of quinquennial periods and even of decades. For, in the first place, the trade cycle is hardly ever exactly ten years long, though it approximates to it; so that it is impossible to get exactly comparable points on the curve of depression or expansion; and, in the second place, the number of years that are in some way or other exceptional, owing to wars and famines and the like, is not small, and even 1872 is only more abnormal than many others. Under these circumstances one must do one of two things—take the figures as they come and be content with the general impression the line produces; or adopt elaborate statistical devices and average each year with several before and after. This has been done by the distinguished statistician, Mr Bowley, in his well known *Elements of Statistics*, published before the discussion began; and there it is equally clear that, to use his own words,[1] "a change of direction" becomes visible about 1872 in the line indicating our exports. The upward movement since has been more laboured and far less buoyant (to use no stronger term), than in the twenty years before 1872. Even if we rule 1872 out, and flatten the curve a little at that point, we should have to say that between 1870 and 1880 this slackening made itself evident. That is the fact; the forecast it suggests is another thing.

III. People, however, who are determined to take a cheerful view of the situation, are accustomed now to fall back on the undoubted fact that there has been a considerable fall in general prices, so that stationary values of exports represent an increasing quantity. The changes on the level of general prices in the United Kingdom, between the years 1801 and 1902 have been carefully worked out by the Board of Trade, following in the footsteps of Jevons and other economists, and expressed in the form of a chart, in its special report on Wholesale and Retail Prices; and this has been reprinted as a Frontispiece to the Fiscal Blue Book, as if to say that all that follows is to be interpreted in the light of the movement of prices.

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[1] *Economic Journal*, September, 1903.

But now we have to ask ourselves whether the fact that for thirty years we have been selling largely increasing quantities of goods for slowly increasing sums of money is necessarily a comforting thought. It seems to me that it all depends on the circumstances of particular trades, and that the matter needs far more detailed analysis than it has yet received. In cases where there has been a great fall in the cost of raw material—as in the case of the woollen manufacture—or where there has been a great cheapening in the process of production, an article may sell for half its former price, and yet give the same or even a higher profit and wage to the employer and the employed. But in other industries a fall in prices may mean lessening profits and employment. And when we lump all the exports of the country together, and "adjust" or "correct" the actual values by the Board of Trade index numbers, we get a result which really means nothing except that more goods were actually sold. As an indication of the state of trade such figures and the chart based on them may easily be very misleading. Thus you will see in the chart which I now exhibit, which has appeared in a well known free trade journal, that the line of "corrected" values soars upward from 1882 to 1890 with only a slight crook about 1885. But in reality the years 1883-6 were years of great and wide spread depression, due to the very low range of prices. Profits were low, and employment in most industries was scarce. In this case the simple figures of export values represented by this other Board of Trade chart, with its great gulf of depression between about 1882 and 1888, are really a truer indication of what was really happening in the country than any "corrected" or "adjusted" statistics.

But there is also another consideration which is commonly overlooked. The Board of Trade prices chart gives the level of prices for the whole of the 19th century; and it will be seen on the most cursory inspection that, if there took place a great fall between 1873 and 1896, there also took place a great fall in the years before the Repeal of the Corn Laws. The shape of the two lines which set forth the fall is not quite the same, but there is a substantial similarity in their form. If the fall in the 23 years, 1873 to 1896, can be represented by the index number 49, the fall in the 23 years, 1818 to 1841, was almost exactly the same, viz., 47. But what is sauce for the Protectionist, is sauce for the Free Trader. The older free trade writers used to have no hesition in taking export values as indications of the state of trade. And so Professor Fawcett, in his well-known book on *Free Trade and Protection*, speaks of trade as "showing little development" and even as "stagnant," between 1815 and 1841, because the value of exports was the same in the two years. If the argument is sound for that period, it is sound for the years 1872 to 1899. If, on the other hand, the figures for the latter period are not alarming, and need to be adjusted with due reference to the fall of values, then those for the earlier period must be similiarly adjusted, and we reach the conclusion that trade was progressing satisfactorily under Protection. I do not come to that conclusion myself: I only want to show where the argument would lead us.

IV. I have already granted that, taking the total mass of exports, there must have been an increase of quantity during the last 30 years. But we have now to observe that this does not apply to a number of the staple industries of the countries for which we are fortunate enough to possess quantity figures as well as mere values. I don't know where you can find these put together in a convenient shape, except in my own little book on *The Tariff Problem;* but the figures are taken from the Statistical Abstracts annually published by the Board of Trade, and these latter are early accessible. It will be seen that the whole group of textiles is declining or stationary in the quantity of its exports. The figures for cotton piece goods have moved but slowly upward since 1894, and seem to have had an increasing difficulty in maintaining themselves; cotton yarn reached its maximum of quantity exported in 1884; worsted stuffs in 1872; cloths and coatings in 1895; linen piece goods in 1873; jute goods in 1891. Similiarly iron and steel and manufactures thereof (excluding machinery and ships) reached their maximum in 1882; and among minor entries in the list, cutlery and hardware reached their maximum quantity figures about 1882.

That is—since the total quantity has increased, while the quantities of these staples decreased—these would seem to be taking place a great shifting of our industrial activity from the old staples to comparatively new businesses. And this is confirmed by the figures in the Fiscal Blue Book which show the number of workpeople as falling off since 1891, not only in agriculture, but also in the cotton and woollen groups, and increasing only 7 per cent., *i.e.*, at a considerably lower rate than the population, in the iron and steel group.

This then is the fact: our interpretation of the facts is quite another thing. What are the occupations to which the country is turning instead? Well among others it is pretty certain that shipbuilding is one. As to the number of people employed, the Board of Trade leaves us in the lurch. It gives the figure for "machine making and shipbuilding," lumped together in the census returns, down to 1891, and then remarks that in 1901 a different classification was adopted, which makes it impossible to give a comparative figure. But we find in another place that the tonnage of steam vessels built in the United Kingdom, while it fell from about 2,900,000, the total in the years 1888-1892, to 2,800,000 in 1883-1897, rose in 1898-1902 to 4,400,000; and though as a slight offset against this we must reckon the falling off in the build of sailing vessels, there can be no doubt there was a substantial advance.

The other directions in which we are developing are of a more questionable character. Foremost among them is coal. The number of our miners is increasing with extraordinary rapidity—from 383,000 in 1881, to 519,000 in 1891, and 648,000 in 1901. And our coal exports are, I need hardly say, growing even more rapidly than our coal output. We exported the following percentages of our output—in 1870, 12; 1880, 16; 1890, 21; 1900, 25. In value coal in 1870 was 3 per cent. of our total exports; in 1880, almost 5 per cent.; in 1890, 9 per cent.; in 1900, 16 per cent. These are the figures of Mr Thomas, whose remarkable paper on coal exports, published last September in the Journal of the Royal Statistical Society, ought to be known to all seriously interested in the subject. As Mr Thomas points out, it is the growth of the coal export which has cloaked the stationary condition of our other exports. It is a comfort to be able to quote the words of one who, as a Liberal M.P., writing before the fiscal issue was raised, is above suspicion: "There is ground for something more than a suspicion than our exports, other than coal, both in respect to value and quantity, have become, at least for the time being, stationary, if not retrogressive."

This then is the fact—and again we have to distinguish between the fact and the interpretation. I know that much of this exported coal is really needed for our own shipping abroad; though it can hardly be that element in the demand which is most quickly enlarging itself just now. But I have not time to labour the point, and must content myself with the mere expression of my feeling that the disproportionate growth of our coal exports is, politically and economically, a matter to cause disquietude. Others, no doubt, will continue to think otherwise, and either to pooh-pooh all alarm, or accept the situation, like Mr Thomas, with a sort of resigned despair.

And then, in the next place, there is a whole group of minor industries which are entering more and more into our foreign trade—such as the manufacture of apparel and slops, oil and floor cloth, rubber goods, etc.—and of which it must be said in general that they employ a low grade of illpaid and largely female labour in our great cities—labour which is quite unorganised. Once more opinion will differ as to the way in which this should be regarded. Some will congratulate the country on a growing variety in its industrial life; and some will say that the conditions of labour in the staple industries, whose decline I seem to deplore, are after all not so obviously better than in these new occupations. For my part I look at the matter from the point of view of "organised labour." With all its faults and defects, I regard the social mechanism which has painfully been created for the adjustment of labour difficulties between combinations of the employers on the one side, and combinations of the workpeople on the other, as among the greatest advances of civilisation, and the only real alternative in the long run to the socialistic intervention of the the state. And I should regard, with the greatest anxiety, the weakening of the trades which are already fairly well organised, and the enlargement of the area of unintelligent and quite unorganised labour. For the lives of the people employed in these low-grade city occupations, I would refer you to the remarkable paper by Mr Masterman—who has recently (to my regret, so far as he personally is concerned) failed to secure election to Parliament—in the volume called the *Heart of the Empire.*

It is a fundamental doctrine of Ricardo and of the orthodox economists that every nation tends to produce and to exchange for the goods of other nations those commodities in the manufacture of which it enjoys a differential advantage. And I can't help thinking that, as things are at present, the chief advantages Great Britain enjoys are the possession of a large quantity of steam coal, and, as compared with the United States and our Colonies, of a large supply of cheap low-grade labour. And as things are, we shall be driven, I think, more and more, to pay for our food and raw materials, by exhausting our coal and developing the cheap labour trades.

V. I cannot now enter into a discussion of all the causes which are endangering British industries. Various forces are contributing to that result; but undoubtedly the protective policy of other nations is among the most important of them. The large facts of the case will be found in the Fiscal Blue Book, which concludes that "there can be no doubt as to the effect of Continental and American tariffs in checking our export trade, especially in manufactured articles, with the group of 'protected countries' during the last two decades."

It appears from the tables there given, that the percentage of exports of *manufactured* articles sent to protected countries and colonies (including Canada and Victoria) fell steadily from 57 in 1850 to 38 in 1902. As the percentage of *all* articles of British produce fell only from 56 to 42, it follows that the proportion of manufactured goods to total exports to protected countries has been decreasing; and so it has, from 96 to 72 per cent. These figures must be taken subject to all the "cautions" which their authors attach to them; but they are the best that the Board of Trade can produce.

And now once more will appear the divergence of judgment. Some will say that this only shows that while some markets are being closed to us we are opening others, and that this can go on *ad infinitum.* Others will point out (turning to the other tables in this Memorandum), that the bulk of our trade has been sustained of late by the growth of our trade with such of our Colonies as have not yet set up effective protective barriers. They will anticipate that the trade with protected countries will continue to dwindle, so long as we pursue our present policy: that unless we offer them a sufficient inducement to do otherwise, our Colonies will follow their example and similarly exclude our goods: and I am inclined to agree with them. The result will be that we shall be driven further and further afield for fresh markets: we shall clamour more and more for "open doors" in countries like China; and we may be quite certain that "open doors" will mean "spheres of influence," and "spheres of influence" will mean annexation. I am sufficient of an old Radical to have no relish for increasing our responsibilities in a country like China; and I must confess that the bellicose tendencies of a "free trade" policy give me some alarm.

A striking example of the effect on our trade of the recent policy of other countries is furnished by the tin plate industry. One almost despairs of getting people to distinguish *facts* from their *opinions* about them, when one sees that they still go on bandying assertions to and fro, although the figures have been published in the Blue Book for everyone to see since last September. What are they? They are briefly these: that under the M'Kinley and Dingley Tariffs, the export of British tin plates to the United States has fallen off from about £4¼ millions to less than £900,000 worth. I suppose most of us know that there are special circumstances which enable us to sell even that much, and that our hold on this surviving fragment of American business is very precarious. But let that pass. Meanwhile our exports to other destinations have grown from £1·4 m. to £4·3 m., so that our total export is now 75 per cent. of what it was before the M'Kinley Act. Here then, in any case, is a loss of a quarter of our trade. But even this represents a recovery from greater depression. A few years ago our trade was only 56 per cent. of what it had been.

These are the facts in the case, let us view them how we will. When I think of the distress which so sudden a dislocation of a great trade must have produced, when I think of the emigration to America of many of our tinplate workers to help in the establishment of the industry there, my confidence in what are called "economic harmonies," in the all-healing virtues of the "transferability of capital and labour," receives a severe shock. Moreover, all who have the slightest knowledge of American politics will recall that the establishment of a high protective tariff in order to call a tinplate industry into existence was fought desperately at one time, with a good prospect of success, by the whole of the Democratic party in the United States. I cannot but think that if Great Britain had at that time possessed any power of negotiation the measure might not have passed, and American energies might have turned into another direction.

VI. And now finally with regard to dumping—the selling abroad cheaper than at home. In my little book on *The Tariff*

Problem,[1] I have tried to show why this is no result of foreign malignity, but the necessary outcome of modern business conditions, and especially of the greater part now played by fixed capital, and the necessity of spreading fixed charges over as large an output as possible. All great manufacturing countries dump when they are driven to it, and this country has dumped, is dumping, and will continue to dump. But any recriminations are quite out of place and do not affect the situation one whit. The only question worth asking is which countries can dump with greatest effect. Evidently so long as our home market is undefended, we fight the dumping duel with one hand tied behind our backs. Moreover protection, while it by no means creates trusts, makes it easier to maintain them; and trusts can carry out a dumping policy with far greater vigour and persistency than individual competing producers. In the Blue book will be found a long memorandum on the subject—not particularly well put together, but still giving a good deal of information. I will pass over the present German competition and limit myself to one quotation with regard to the United States. "The available evidence goes to show that for some time past the United States has for the most part been able to absorb a great proportion of its total output, and that during this period of exceptionally good trade, the inducement on the part of the trusts to dump goods in foreign markets may fairly be considered to have been slight, as compared with what might be manifested in a time of industrial depression" This is as far as official caution will go. But of course, we all know that the steel-makers of this country are living in dread of what is going to happen when the wave of depression, now overdue, sets in in the United States. And the question one may fairly ask is this. Supposing we knew as a certainty that our steel manufacture was going to be killed—granting if you like that for a time shipbuilders and other users of steel could get it at an extravagantly cheap price—are we prepared to face the dislocation of business which the blow would involve and to trust to free trade to finally redistribute labour and capital to other employments, and are we prepared to become dependent on foreign countries for the most important of all the munitions of war? I can conceive people so idealist and utopian that they are ready to face even that; but I think we ought all to begin to make up our minds, for it is a contingency in my judgment which is not far off.

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[1] Pp. 83-98.

I am sure I have occupied enough of your time for one evening. There are many other topics on which I should have been glad to have spoken, such as the effect of duties on the price of food and the relation of the price of food to public well being, as well as on the rates of wages in various countries. But for these again I must refer you to the Blue Book, which you will get, I hope, as a New Year's gift. I shall be satisfied if I can show that there are facts of the utmost importance on which all sensible and honest men can agree, however we may continue to disagree as to the conclusions to be drawn from them.

CENTENARY LECTURES, NO. V.

Developments in the Means of Communication by Sea during the Nineteenth Century. By ROBERT CAIRD, LL.D.

[Prepared by request of the Council and delivered before the Society, 6th April, 1904.]

IN reviewing the progress made during the 19th century in the means of communication by sea we have not, especially in presence of a lay or popular audience, the same opportunities of exciting surprise that the representatives of chemistry and physics have had. Ships, whether sailing or steam, are and have always been so interwoven into the daily life and interest of the people of these isles, that there is practically nothing to be said of them which is not perfectly well known, perfectly familiar. Many thousands of our population are engaged in the construction of them : many thousands more in the manning and loading of them : and there is probably no member of the empire who has not had occasion to use them in the transport of himself and his goods. There are of course many technical points in connection with these ships, many applications of science that are accepted and taken for granted, but which are by no means obvious, and only implicitly recognised. Just as in the instinctive movements of the muscles in locomotion, we accept the results unquestioningly, indifferent to, and therefore unperplexed by, the physiological problems involved in them.

As, too, gravitation force, that greatest and most impenetrable of the mysteries in the world of physics, has become degraded in our experience into a mere measure of weight until we have ceased to wonder at it, even to respect and acknowledge it. So that perhaps the only way to reawaken the sense of wonder is to recall the difficulties that have been overcome, and the slow and painful nature of the steps that have had to be taken in overcoming them.

The period under review is practically the 19th century—more exactly from 1802 till 1902, covering the first hundred years of the existence of this Society—coincident as nearly as possible with the first century of Steam Navigation. For when this Society was founded here in November, 1802, Symington's "Charlotte Dundas" was laid up a few miles away at Lock 16 of the Forth and Clyde Canal, after having successfully demonstrated the power of steam to tow a couple of laden sloops of about 70 tons at a speed of 5 to 6 miles an hour.

It is unnecessary to point out that the application of steam power to propulsion was a direct result of Watt's discoveries and improvements on the steam engine. Earlier attempts on other lines by Symington himself were hopeless failures. The eminently simple direct-acting horizontal engine of the "Charlotte Dundas" embodied at least three of Watt's epoch-making mechanical improvements, the closed cylinder, the separate condenser, and the conversion of reciprocating into rotary motion by means of the crank and connecting rod.

This last, really Murdock's adaptation, was not considered patentable by Watt, who looked upon it as one of the oldest mechanical applications in existence; as he himself said, "The true inventor of the crank rotative motion was the man who first contrived the common foot lathe." However, it was patented by Pickard by an act of piracy, if we are to credit the biographers; and Watt, in his pride as an inventor, and to retain control of every part of his engine, substituted for this simplest of devices, his ingenious, if complicated and cumbersome, sun and planet motion. His original intention was, however, undoubtedly to use the crank, so that there is no historical inaccuracy in attributing its adoption in steam engines to his initiative.

The "Charlotte Dundas," having served the purpose of a demonstration of the practicability of the use of steam as a motive power, became an object lesson to enthusiasts, chief among whom were Robert Fulton and Henry Bell.

The first is known to fame in connection with the "Clermont," a vessel of considerable size, some 130 feet long, propelled by an engine of 18 H.P., made by Boulton and Watt. This steamer, built in 1807, did regular service on the Hudson River, and may fairly claim to be the first really practical adaptation of steam to marine propulsion: although that claim might have been disputed had the owners of the little "Charlotte Dundas" been enterprising enough to take her out of the canal and venture upon the navigation of the Clyde.

Nearly ten years elapsed before a second attempt was made in Scotland, so slow was the growth of conviction on the part of practical men as to the real value of the new method of propulsion. This caution is remarkable in view of the enormous extension of the use of steam engines for land purposes during this decade of distrust. It may have been due in some measure to Watt's own reluctance to embark on new ventures, and to the opinion he had expressed "That there may be considerable difficulty in making a steam engine to work regularly in the open sea, on account of the undulating motion of the vessel affecting the vis inertiæ of the matter." The attempt of Henry Bell proved the real starting point of the great industry of marine engineering on the Clyde. In 1812 he had the "Comet" built for him by Wood of Port Glasgow. She was a tiny craft of 25 tons burthen, measuring 42 feet long by 11 feet beam, and drawing 5 to 6 feet of water. Her engines, or at any rate the forged parts of them, were made at Greenock by Anderson & Campbell. Her engine was of 3 horse-power, with a cylinder of 12½ in. diameter, and she is said to have steamed at the rate of 5 miles an hour under favourable circumstances.

The introduction of elaborate series of statistical figures into such a paper as this would be manifestly improper, and destroy any interest it might possess; but to illustrate the century's progress, it may be permissible in one or two cases to make a comparison of the dimensions of representative steam ships at the beginning and end of the epoch.

It may be objected that it is scarcely fair to take the "Comet" as a basis of comparison, at any rate for size, because of course there were then afloat many sailing vessels of much greater tonnage.

Indeed when the 19th century opened the average tonnage of the 18,000 sailing ships of the mercantile marine of the United Kingdom and her Colonies was nearly 100, or four times that of the "Comet": some of the largest measuring from 1,300 to 1,400 tons. If, however, steam vessels alone are considered and our survey limited to this country the objection falls.

For that purpose the "Comet" has been chosen at the low end of the scale, and she may fairly be compared with such a steamer as the "Baltic"—the largest vessel under construction at the date of our centenary celebrations—to mark the extreme limits of the developments in steam navigation from the point of view of size of vessels. The "Baltic" is 725 feet long; 75 feet beam, and 49 feet deep; and measures 24,000 tons gross; her cargo capacity is 28,000 tons, and her displacement at load draught 40,000 tons.

The speed for which she is designed is from 16½ to 17 knots; to propel her at which, she is fitted with two sets of Quadruple expansion engines developing 13,000 indicated horse-power and weighing about 2,600 tons.

This huge vessel is thus seen to be, in comparison with the "Comet," one thousand times larger, four thousand times more powerful, and three-and-a-half times faster, while the "Kaiser Wilhelm II." has fifteen thousand times the power of the "Comet" and steams five times faster.

Surely so great an advance is worthy of the wonderful century that has gone. It implies a continuous activity and progressive development in the arts which contributed to the construction and equipment of steam vessels and their machinery; an alert recognition of the ever changing conditions which each fresh step imposed, and a sublime courage in sacrificing whole fleets obsolescent before pride in them had had time to cool.

The Atlantic Ferry has naturally been the scene of the greatest developments in maritime transport. The first steamship to cross the Atlantic was the "Savannah," a wooden vessel of 320 tons, built in America. Her steam power was merely auxiliary, the paddles being shipped and unshipped; indeed on the passage of 29 days 11 hours, from Savannah to Liverpool in 1819, steam was only used for 3 days.

The first vessel to steam all the way across was the "Royal William," of 830 tons, in 1833, with side lever engines of 200 nominal H.P. by Boulton and Watt. She took 38 days to cross from Quebec to London, at a time when sailing ships were making the passage in from 17 to 22 days. It is impossible to overrate the courage and enterprise of the pioneers of this service in the face of the difficulties and discouragements they had to encounter, difficulties arising not only from perils of the sea and the crude nature of the apparatus at their command, but also from the scepticism of contemporaries, even of learned scientists. You remember Dr Lardner's famous, if rash prediction, in 1835 "as to the project, however, which was announced in the newspapers lately, *i.e.*, of making the voyage directly under steam between New York and Liverpool, it was, he had no hesitation in saying perfectly chimerical, and they might as well talk about making a voyage from New York or Liverpool to the moon."

His calculation was based upon an estimate of the fuel required on so long a passage, and the inability of vessels of ordinary dimensions to carry it.

Within three years, however, the "Sirius" and "Great Western" generally considered the pioneers of the Atlantic Steam Service, successfully accomplished the supposed impossible feat, and reduced the passage from 17 to 13½ days. They were wooden paddle steamers, with side lever engines of what may be called the land type, and consumed respectively 24 and 33 tons per day, averaging about 8½ knots. The "Sirius" is remarkable in that she was fitted with Hall's surface condensers. These vessels inaugurated in 1838 a regular Atlantic Service, which has never since been discontinued. This date corresponds closely with that of the classification of the first iron steamer in Lloyds' Register, with the introduction of the screw propeller, and with the founding of the Peninsular and Oriental Company, all in 1837. The change from wood to iron as the principal material of construction in shipbuilding was a most momentous one to us as a nation, for our home supplies of timber were being rapidly exhausted; and America, in virtue of her vast forests of magnificent trees of every variety was fast gaining upon us in the amount of tonnage turned out annually, and did actually surpass us just before the outbreak of the Civil War in 1861. There was in these early days a popular prejudice against iron because it was considered that it would not float, a prejudice that died hard, and not until the behaviour of the "Great Britain" in 1846, after being ashore in Dundrum Bay for nearly a year, demonstrated the capabilities of iron to withstand treatment to which a wooden ship would certainly have succumbed, were even professional shipbuilders converted to a full faith in its usefulness.

Iron had been employed as early as 1788 in the construction of barges for the Severn by John Wilkinson, who made all Watt's castings for him before the opening of the Soho Foundry; and several vessels were built of it before 1837. Its introduction was, however, slow as may be seen from the fact that no rules were formulated regulating iron scantlings by Lloyds' Register until 1854, and then the preface opened with the significant words: "Considering that iron shipbuilding is yet in its infancy." It was a tolerably vigorous infancy which included such vessels as the "Great Britain" and the "Atrato," and was already engaged on the design of the "Great Eastern." The first steamers of the Cunard Company, which began operations in 1840 were built of wood—the last of this material being the "Arabia" in 1852, of 2,400 tons and 2,900 indicated horse-power. The first iron vessel of this great Company, which, since 1840, has maintained an uninterrupted service across the Atlantic, was the "Persia," built in 1855.

Last winter the Cunard Company issued a handbook for the use of passengers containing *inter alia* a very compact diagram showing the growth in size and power of the vessels of their fleet. Twenty-nine representative steamers are shown to scale, grouped according to material of construction and means of propulsion. Wooden vessels, from 1840 to 1852, and from 220 to 280 feet long, were all paddle steamers, steaming from 8½ to 13 knots, of a gross tonnage of 1,154 to 2,400 tons, and an indicated horse-power of 740 to 3,250.

The era of iron inaugurates much greater size It extends from 1855 to 1879, and shows a slight increase in length, from 376 to 430 ft., but the *first* iron ship was nearly 100 feet longer than the *last* wooden one. When paddles were replaced by screw propellers in 1862, the length was reduced by about 50 feet, and then gradually increased in successive ships; tonnage increased from 3,300 to 4,500; horse-power from 4,000 to 5,300; and speeds from 13·8 to 15½ knots.

From 1880 onward Siemens-Martin, or what is called "mild" steel, has taken the place of iron, and the steamers of this company have increased in length from 515 feet in the Servia to 600 in the famous "Campania" and "Lucania"; and since 1890 the single screw has given place to the twin; tonnage has risen from 7,400 to 13,000; horse-power from 9,900 to 26,000; and speed from 16·7 to 22 knots. These figures may be taken as representing pretty fairly the general practice of the greater Companies.

The Cunard has not always held the blue ribbon for size or speed even in this country—it had to yield the palm to the Collins line, the Inman, White Star, and Guion lines successively; but it has never retired from the competition, and periodically takes its place in the van. While therefore the official diagram must not be taken strictly as an indication of the earliest adoption of the leading features in the progress of steamship design, or always of the greatest advance in size or power at any given time, it presents a broad view of the gradual growth of British Shipping of the highest class. The most striking feature in the progress thus shown is that the passage from New York to Liverpool is now made in little more than one-third of the time occupied in 1840, and that the time-saving is accompanied by an increase in tonnage of 12 times, and in power of 35 times. Had the tonnage not been increased the power for 22 knots would only *ceteris paribus* have been 14 times that necessary for 9 knots. But for the improvements in marine engineering the "Campania" would require 2,450 tons of coal per day instead of about 450; that is to say she would consume as much in one day as she now does on the whole trip.

Perhaps the most wonderful instance of engineering skill—considering all the circumstances of the knowledge then in existence of the properties of iron, and of precedent in the matter of size and power is afforded by the "Great Eastern." In his Presidential address to the Institution of Civil Engineers at the opening of this session, Sir Wm White made a most appreciative reference to the genius and skill of Brunel and Scott Russell, her designer and builder respectively; and made a comparison between this great ship and some of the most recent vessels of similar size, from the point of view of structural weight and strength, which cannot but increase our admiration for the foresight and ability of these pioneers in iron shipbuilding.

Brunel in 1851 began to consider the question of a steamer to carry her own coal out and home on an Australian voyage at a high rate of speed. Two years later arrangements were made for her construction. At that time the largest iron steamers were the "Himalaya" of the P. & O. Company, and the "Atrato" of the Royal Mail Company; the first 340 feet long, 3,400 tons gross, 4,000 tons displacement, with 2,000 H.P. and 12 knots speed; the "Atrato" 315 feet long, 3,460 tons gross, 4,000 H.P. and 13½ knots speed.

The boldness of Brunel's achievement may be realised when we consider that he designed and built the "Great Eastern," of double the length of the longest steamer then existing, of five times the tonnage, and twice the power. The "Himalaya" was then "too large for the commercial work of that day," as Sir Thomas Sutherland tells us. What would be thought to-day were a ship-builder to propose to build a steamer greater than, say, the "Kaiser Wilhelm II." in these ratios?

The "Great Eastern's" particulars were as follows:—

Length, 680 feet.
Breadth, 83 „
Depth, 58 „
Tonnage, 19,000, nearly (gross).
Displacement 30,000 tons on 30 ft. draught.
„ 32,700 „ on 34½ „ „
(when Cable laying in 1870).

Her power was about 8,000 indicated. Nearly half a century elapsed before vessels of greater size and tonnage were built. Her power was developed as to 60 per cent. in screw and as to 40 per cent. in paddle engines, and the speed at sea was practically that aimed at by her designer—14 knots. Sir Wm White has drawn attention to some of Brunel's statements which are well worth preservation—"The use of iron," he remarks, "removes all difficulty in the construction, and experience of several years has proved that size in a ship is an element of speed, strength and safety, and of greater relative economy, instead of a disadvantage, and that it is limited only by the extent of demand for freight, and by the circumstances of the ports to be frequented."

It is a most interesting thing that from a technical point of view, the problem was completely and successfully solved notwithstanding the dangerous character of the speculation commercially.

I abstract the following from Sir Wm White's paper in corroboration: "having carefully looked into the matter in the light of present knowledge, I am of opinion that the estimate of power required to drive the 'Great Eastern' at 14 knots, with an average draught of about 25 feet, is practically identical with that which would now be made for the ship if propelled by twin screws." And further: "As to strength, the vessel was severely tested during the thirty-two years she remained afloat. She carried enormous loads of submarine cables, encountered very severe weather, ran on the rocks off Montauk Point, and tore a hole in the outer skin, 80 feet long by 10 feet broad, but proceeded to New York, her passengers being unaware of the damage done. She was repeatedly beached on a 'gridiron' on the Mersey and at Milford Haven for repairs: yet throughout this service no signs whatever of structural weakness occurred, and local damage was readily made good."

And lastly, on the question of relative weight:

"I have most thoroughly investigated the question of the weight absorbed in the structure of the 'Great Eastern' and my conclusion is that it is considerably less than that of steel-built ships of approximately the same dimensions and of the most recent construction. Of course these vessels are much faster, have more powerful engines, and have superstructures for passenger accommodation towering above the true upper decks which form the upper flanges of the girders. These and other features I cannot now specify, involve much additional weight, and the 'Great Eastern' has the advantage of being deeper in relation to her length than the modern ships. After making full allowance for these differences, my conclusion is that the 'Great Eastern' was a relatively lighter structure, although at the time she was built, only iron plates of very moderate size were available." Brunel found himself hampered by established practice and expressed his belief, one shared by many a designer since his day, "that we should get on much quicker if we had no previous habits or prejudices on the subject."

Coincident with the adoption of iron in shipbuilding was the introduction of the screw propeller, the credit of which is largely due to Thomas Pettit Smith, although many experiments had been made, extending over half-a-century, after Watt's famous letter to Dr Small in 1770, containing the oft-quoted words: "Have you ever considered a *spiral oar* for that purpose, or are you for two wheels?" The sketch accompanying that query clearly showed that the principle of the screw propeller was present to Watt's mind. Smith's classical series of comparative experiments with the "Archimedes" and "Widgeon" brought the advantage of the screw prominently forward and inaugurated the era of the propelling instrument which has been perhaps the most important factor in the development of steam navigation during the last half-century. And yet it is astonishing how little is known about it! These two inventions, or discoveries, or adaptations, or whatever they may be called, rendered possible, and promoted the great extensions of ocean navigation to the East, the Pacific, the West Indies, to South Africa, indeed to every part of the navigable globe, which are associated with the names of the Peninsular and Oriental, Pacific, West Indian, Royal Mail, and

Union and Currie Companies. The first of these deserves more than a mere passing notice as being the first in order of date, and the great link with our vast Eastern possessions and Australian Colonies.

A very succinct and interesting historical retrospect of the operations of this company by the chairman, Sir Thomas Sutherland, is to be found in the P. & O. Pocket Book for 1887, the year of its jubilee, supplemented in 1900, from which the following particulars are extracted. Beginning with vessels of about 500 tons the mail service to Gibraltar was opened in 1837—the Indian and other Eastern mails being taken on by Government steamers to Malta and Alexandria. The time occupied was about a month to Alexandria and two months to Bombay, as against less than 4½ days and 15 days respectively now. Soon the company's operations were extended to Alexandria, and three years later to Calcutta, taking up the Calcutta-Suez portion of the through service. The Bombay service was taken over a few years later from the East India Company, and the China ports and Australia—the latter in 1852—were also included in the sphere of the undertaking. So that the whole East was embraced in a network of ocean lines under one company, forming a sea link with the Mother Country interrupted only by the neck of land between Suez and Port Said. The first contracts with the Government were for a monthly service—now the mail steamers of the company run weekly to Bombay, and fortnightly to Australia and to China, having been gradually increased in size from about 2,000 tons to 10,500, and in power from 2,000 horses to 11,000, the increase in speed being about from 10 to 18 knots. The scheduled time from London is now 15 days to Bombay, 32 to Melbourne, and 35 to Shanghai, but the due dates are often anticipated by as much as three days on the longer routes, while the regularity with which the whole business of transport is conducted is one of the greatest tributes to the engineering efficiency of modern means of communication by sea. The fleet is now composed of 62 vessels of 365,000 tons register, and about 358,000 horse-power—the average size being 5,900 tons.

The long and honourable career of this company has been by no means unchequered. Probably the most momentous and critical event in its fortunes was the opening of the Suez Canal in 1869, which necessitated a complete reorganisation of its business and reconstruction of its fleet. That event coincided with its adoption of the compound engine—somewhat later than some of the other great lines, notably the Pacific Company, which had successfully introduced it in 1856. The great reduction in consumption of fuel which this improvement in marine engineering effected, while it rendered the problem of long distance steaming easier of solution, had the counterbalancing effect of enormously stimulating competition. The result has been a reduction in rates of freight of a quite unprecedented character. In Sir Thomas' words, "It is a tolerably safe proposition that neither the agricultural interest, nor that of railways, nor any other extensive industry has encountered such a revolution as the Mercantile Marine has experienced and successfully applied within the last quarter-of-a-century, on this point it is enough to say that Eastern freights may be set down at about a fifth of what they were previous to the opening of the Suez Canal."

The Directors of the Great Eastern Company based their calculations of earnings on overhead freights of from £7 to £5 per ton—goods are now carried by the P. & O. at a rate of less than $\frac{1}{35}$ of a penny per ton-mile, which works out at about 30s. for Australia, and 25s. for China.

Another of the effects of the piercing of the Isthmus of Suez has been the gradual but unrelenting supersession of sailing ships by steam, even on the longest routes, due in great measure to the continuous improvements in marine engineering, tending to increased economy of fuel, to the multiplication of coaling stations, and to cheap conveyance of coal to distant points.

The change is generally attributed to the greater regularity of steam service; but it must be confessed that up to 8 or 9 knots there is little to be complained of as regards variation in the average passages of sailing ships on the great Trade routes. The "Thermopylae" made two consecutive voyages from London to Melbourne, the first in 60 and the second in 61 days; and the famous China clippers in the sixties used to arrive in the Thames within a few hours of one another after leaving China together.

Without attempting to trace the developments in sailing tonnage it may be sufficient to give the particulars of one of the largest of the modern vessels—the "Potosi"—built in Germany in 1896. Her dimensions are 360 × 49½ × 31, tonnage 4,026; deadweight capacity, 6,200 tons; displacement, 8,470 tons at 25 ft. draught; her spread of canvas is over 50,000 sq. ft., and her average speed on voyages of from 6,000 to 14,000 nautical miles, from 8 to 9½ knots.

The statistics of last year show that while 622 merchant steamships of over 2,200 tons average were built in this country, only 62 sailing ships of 700 tons average were added to the Register; that is to say, only $\frac{1}{28}$ of the new tonnage was sailing. The figures given to show the growth of steamships in the case of the Cunard and P. & O. Companies may be taken as typical of the progress in size and power in the case of the other great lines—the White Star, Union Castle, Pacific, West Indian Royal Mail, Allan and Anchor. It is worthy of note that the largest vessels on the longest routes are approximately of about the dimensions of Atlantic steamers built ten to fifteen years earlier, as may be seen by comparing the steamers of the Cape Mail and Australian lines with those of the Cunard and White Star Companies. With the development of traffic on the principal trade routes there has sprung up a class of intermediate passenger and cargo steamers of great carrying capacity and moderate speed. The Cunard "Carpathia" may be taken as a type of the class on the Atlantic, and the White Star "Suevic" on the Australian route via the Cape. The "Carpathia" has a length of 560 ft., measures 13,500 tons; and steams 15 knots with 8,000 H.P. She carries 200 Second Class, and 1,800 Third Class passengers. The "Suevic" is 550 ft. long, 63 ft. broad, of 12,500 tons and 5,000 H.P., and steams 13 knots, with a coal consumption of 80 tons per day. Sir Wm White makes a most interesting comparison between this latter steamer and the "Great Eastern," showing that on the conditions which Brunel set before him, namely of carrying sufficient coal to circumnavigate the world, the "Suevic" could carry 8,000 tons of cargo on the out trip to Australia, and 11,000 tons on the home trip.

In this short summary or retrospect of the growth of merchant shipping during last century attention has been directed almost entirely to British vessels and to those of the largest size. The strides made have certainly been enormous, and these few notes give a sufficiently representative view of the developments in size and power. It remains only to further indicate the means by which such growth has been rendered possible, first as regards the materials employed in the construction of hulls and engines, and secondly, as regards improvements in design and in the application of well known mechanical principles.

It has already been shown how and when wood was replaced by iron, and the extent to which the change influenced the size of vessels. Brunel was certainly sanguine in his estimate of the properties of the iron of his day, and he was apparently justified in it by the performances of his two creations, the "Great Britain" and "Great Eastern." But in course of time and under stress of competition the material, especially in the form of ordinary ship plates, was found in many cases to be unreliable and uncertain. As a matter of history it remained the principal material of ship construction for half-a-century. During that time strenuous efforts were being made to improve the quality of iron, notably by Bessemer as early as 1856, and ten years later by Dr Siemens; but it was not till the late seventies that the new material, homogeneous iron, or mild steel, made by the Siemens-Martin process, came into use. Denny's "Buenos Ayrean" in 1879 for the Allan line was the first ocean steamer in which it was used, although the little "Windsor Castle" which plied on the Clyde as early as 1859 was built of steel—the price at that time being, however, prohibitive.

The Admiralty led with the "Iris" and "Mercury," built of steel made at Siemens' Landor Works in 1875.

Lloyds' tests for iron were 20 tons with the grain, and 18 tons across; and for steel from 28 to 32 tons tensile with an extension of 16 per cent. in 8 inches; and at first a reduction of 25 per cent. in scantlings was allowed. But the greatest advantage of steel over iron was its uniformity of strength, which gave confidence to designers—every plate being tested at the works, and in the case of classified vessels, stamped with the certifying mark of the Registration Society.

Its greater ductility also enables it to be worked cold in a way impossible in the case of iron.

There is no finality in metallurgical processes as we are reminded very forcibly in the recent experiments with nickel steel—a material now in the market, and for which Mr Beardmore claims an elastic limit or yield-point equal to the ultimate or breaking stress of mild steel. That is to say, nickel steel possesses strength within the limit of elasticity of about 30 tons as against 16 tons with Siemens-Martin steel. So that naval architects have here to their hands a structural material nearly twice as strong for purposes of design as what has done such splendid service for the last twenty-five years. What that may mean may be inferred from the fact that the use of steel instead of iron in the structures of the steamers of the Mercantile Marine of the world has saved at least 2½ million tons in weight, and 12½ million pounds sterling in value; and that at no sacrifice, for steel is to-day 20 per cent. cheaper than iron. The saving in coal for propulsion alone due to this reduced weight cannot be far short of 4,000,000 tons per annum, worth at 15s. per ton 3 millions sterling.

I do not think these figures are in any way overstated, and they take no account of savings due to the substitution of steel for iron in the machinery department.

One of the earliest improvements in marine engineering was the adoption of surface condensation—a system which is now universal—by which the waste steam from the engine is condensed without admixture with sea water, a great gain in safety and economy. About the same time the screw propeller as we have seen displaced the paddle, which, in its time had been considerably improved upon, chiefly by Galloway's device of feathering the floats so that they should always work at an effective angle. But the chief loss of efficiency, particularly in large vessels of considerable carrying power, lay in the great variation of immersion of the floats at light and load draughts. The screw, apart from its inherent greater efficiency, remedied this defect to a certain extent. At any rate the single screw remained *the* instrument of propulsion *par excellence* for fifty years.

An attempt was made in the White Star steamer "Britannic" in the seventies to overcome the danger and unpleasantness of racing by the cumbersome device of a raising and lowering propeller, but it was unsuccessful. The best remedy so far, is the twin screw—or perhaps one should say the multiple screw.

The twin screw came into extensive use about 20 years ago, when the enormous powers required on the Atlantic made subdivision into two lines of transmission practically a necessity. It soon came to be looked upon as providing a second string in the event of accident in passenger ships, and it is now almost universal for the largest class of steamer, even of moderate speed. The question of the relative economy of twin and single screws is still a controversial one. It is pretty generally conceded that on a trial trip in smooth water and under favourable conditions of draught the single screw has an advantage of about 10 per cent. over the twin; on the other hand on a voyage with varying conditions of weather and of immersion it is sometimes claimed that the advantage is reversed or that it disappears. Sir Wm White was a pioneer in the advocacy of the twin screw, at any rate for the swiftest steamers, and in his address, to which I have referred, he has the satisfaction of being able to say, "It is pleasant to note that the opinions expressed 25 years ago have been fully justified in later practice."

Mention has already been made incidentally of the change from the single to the compound engine; a change which, soon after 1860 became general and continued until, in 1880, a further development of expansion in one more stage—the triple expansion engine—supplanted it. A still further step to quadruple expansion was taken a few years ago, but has not yet made much headway. Those changes have been accompanied by continuously increasing steam pressures, modifying the type of boilers and calling for more reliable materials of construction. In the early days of steam the pressure was only a few pounds above the atmospheric, and Brunel was thought rash when he insisted upon 25 lbs. for the "Great Eastern." In the days of the compound engine, pressures rose to 100 or 120; and for triple expansion work from 150 to 200 lbs. is about the range. The best quadruples with the ordinary cylindrical boiler are to-day working at 210 lbs. We may take it that the increase of pressure has been 200 lbs., corresponding to a rise in the temperature of the steam of 240° Fahrenheit.

One of the factors in bringing about these advances has been the introduction of the corrugated flue.

As powers increased there has been a corresponding acceleration of the engines themselves. Revolutions gradually mounted up from 30 or 40 to 50, 40 years ago, and now in ocean going steamers of the largest size from 80 to 90 revolutions are not uncommon, with corresponding piston speeds of over 1000 ft. per minute as against the usual figure in the early days of the screw propeller of 400 ft. These figures, however, shrink into insignificance when we consider the practice with torpedo boats and destroyers. Improved design and better material have reduced the weight of machinery relatively to power developed by about one half. In mail steamers 50 years ago a ton of propelling machinery represented 3 horse-power, now it may be reckoned at 6½ horse-power.

Watt's estimate of the duty of his pumping engines was 112 lbs. of coal to do the work of ten men working ten hours a day.

This works out at about 13 or 14 lbs. per hour per I.H.P. Early marine engines consumed 9 or 10 lbs., but as pressures were increased this consumption was reduced to 3 or 4 lbs.; with compound engines 2½ lbs. became normal, and now, good triple expansion engines frequently work at 1¼ lbs., so that ten times the power is now got from each pound of coal.

These are broadly the leading features in the progress made in steam navigation during the century that has passed. There is one advance—the greatest since the days of Watt—which cannot be passed over in silence, although commercially speaking it is still on its trial—*the steam turbine.* The credit of applying the principle to marine propulsion is doubtless due to the Hon. Charles Parsons, whose "Turbinia" (1887) was a revelation to engineers. A little boat of 100 feet long carrying machinery weighing only 22 tons developing nearly 2,000 horse-power and steaming at the rate of 31 knots was so far ahead of anything that had then been attempted that, while the results could not be questioned, there was a distrust in official and business circles which it took years to overcome. The ill-fated "Cobra" and "Viper" sufficiently proved the great merits of the system. But the Clyde has the merit of adopting it in mercantile work, and the "King Edward" and "Queen Alexandra" are familiar objects of pride on the Firth. In Channel service the Parsons turbi-motor has proved so efficient and so reliable that it bids fair to entirely supersede engines of the reciprocating type. And with their two new mail steamers of about 12,000 tons and 11,000 horse-power, now under construction at Belfast, the Allan Company is taking the lead among the Ocean lines in the adoption of turbine engines.

But, just as in the case of the compound and triple-expansion engines, and of the other epoch making improvements in marine engineering, a long and discouraging series of experiments extending over many years had to be made before the turbine became practicable. In the forties a great deal of inventive activity was devoted to rotary engines, and several were constructed which proved commercially successful. It is very difficult to procure authentic data of the working of Gorman's, Ruthen's, and Wilson's rotary engines, and also of other types; one at least was employed in marine propulsion about 1846; but, notwithstanding a possible priority of claim, and notwithstanding the fact that hundreds of patents have been registered dealing with steam turbine engines, Parsons' position as a pioneer is absolutely unassailable.

It has been a source of regret—I might almost say of humiliation—that the leading position for speed on the Atlantic has for the last 5 or 6 years been wrested from Britain by Germany. The only British Atlantic Mail ship of high speed after the "Campania" and "Lucania" was the White Star "Oceanic" which made no attempt to lower the record time, while the Germans with their "Kaiser Wilhelm der Grosse," "Deutschland," "Kron Prinz Wilhelm," and "Kaiser Wilhelm II.," raised the ocean speed from 22 to nearly 24 knots, and to do so had to increase tonnage and H.P. by over 50 per cent.

I do not think it is generally realised that the crack German mail steamers are so enormously ahead of our latest and best. It has been argued that the expense accompanying such revolutionary developments makes them prohibitory, but in to-day's paper (6th April, 1904) you may read the annual financial report of the Norddeutscher Lloyd, recommending a dividend of 6 per cent. on their ordinary shares, a rate some of our more reactionary lines would be glad to be able to show.

It is a subject of congratulation that the Cunard Company, with the aid of H.M. Government, is about to make an effort to regain our lost supremacy. The particulars of the new steamers have just been published; and as the more recent German steamers have been merely expansions of previously existing types, so *with one exception*, these new Cunarders are only magnified Kaisers: about as much larger than the "Kaiser Wilhelm II.," as that steamer is larger than the "Campania." The exception is that Parsons' turbines, fitted to four shafts, are the motive power. I am sure we all look forward to the results with the utmost interest and with the most fervent good wishes for the success of the bold venture.

It has been impossible, in the short time at my disposal, to do more than hint at, or catalogue in chronological order the various developments "of the new and mighty power," in the words of George Canning, "new at least in the application of its might, which walks the waters like a giant rejoicing in its course, stemming alike the tempest and the tide, accelerating intercourse, shortening distances, creating, as it were, unexpected neighbourhoods, and new combinations of social and commercial relations, and giving to the fickleness of winds, and the faithlessness of waves, the certainty and steadiness of a highway upon the land."

ATLANTIC

VESSEL.	CAMPANIA.	KAISER WILHELM DER GROSSE.	OCEANIC.
Built, - - - - -	1893.	1898.	1899.
Owners, - - - -	Cunard Co.	Nor. German Lloyd.	White Star Co.
Length (Extreme),	622 ft. 0 ins.	648 ft. 0 ins.	704 ft. 0 ins.
Length (B.P.), -	600 ft. 0 ins.	625 ft. 0 ins.	685 ft. 0 ins.
Breadth, - - - -	65 ft. 3 ins.	66 ft. 0 ins.	68 ft. 0 ins.
Depth, - - - -	41 ft. 6 ins.	43 ft. 0 ins.	49 ft. 6 ins.
Gross Tonnage, - -	12,500.	14,349.	17,274.
Load Draft, - - -	25 ft. 0 ins.	28 ft. 0 ins.	32 ft. 6 ins.
Displacement, - -	18,000 tons.	20,880 tons.	28,500 tons.
Passengers, - - -	1st. 2nd. 3rd. 600 400 700	1st. 2nd. 3rd. 590 354 640	1st. 2nd. 3rd. 410 300 1,000
Boilers, - - - -	1 S.E. & 12 D.E.	2 S E. & 12 D.E.	15 D.E.
Heating Surface, -	82,000 sq. ft.	84,285 sq. ft.	74,686 sq. ft.
Fire Grate, - - -	2,630 sq. ft.	2,618 sq. ft.	1,962 sq. ft.
Working Pressure, -	165 lbs.	178 lbs.	192 lbs.
Type of Engine, -	Triple.	Triple.	Triple.
Sets, - - - - -	2.	2.	2.
Cylinders, - - -	2·37″ × 79 × 2·98″	52″ × 89·7′ × 2·96·4″	47½″ × 79″ × 2·93″
Stroke, - - - -	69 ins.	68 8 ins.	72 ins.
Speed, - - - -	22 knots.	22½ to 23 knots.	20 knots.
I.H.P., - - - - -	30,000.	30,000	27,000.

LINERS.

DEUTSCHLAND.	KRONPRING WILHELM.	KAISER WILHELM II.
1900.	1901.	1902.
Hamburg American.	North German Lloyd.	North German Lloyd.
684 ft. 0 ins.	663 ft. 0 ins.	706 ft. 6 ins.
662 ft. 9 ins.	——	——
67 ft. 0 ins.	66 ft. 0 ins.	72 ft. 0 ins.
44 ft. 0 ins.	43 ft. 0 ins.	52 ft. 6 ins.
16,802.	15,000.	20,000.
29 ft. 0 ins.	29 ft. 0 ins.	29 ft. 0 ins.
23,620 tons.	21,300 tons.	26,000 tons.
1st. 693 2nd. 302 3rd. 288	1st. 650 2nd. 350 3rd. 600	1st. 775 2nd. 343 3rd. 770
4 S.E. & 12 D.E.	4 S.E. & 12 D.E.	7 S.E. & 12 D.E.
85,468 sq. ft.	93,865 sq. ft.	107,643 sq. ft.
2,188 sq. ft.	2,702 sq. ft.	3,121 sq. ft.
220 lbs.	213 lbs.	225 lbs.
Quadruple.	Quadruple.	Quadruple.
2.	2.	4.
2·36·6″ × 73·6″ × 103·9″ × 2·106·3″	2·34·2″ × 68·8″ × 98·4″ × 2·102·3″	37·4″ × 49·2″ × 74·8″ × 112·2″
72·8 ins.	70·8 ins.	70·8 ins.
23½ knots.	23½ knots.	23½ to 24 knots.
36,000.	36,000	38,000 to 40,000.

On Pseudogaylussite dredged from the Clyde at Cardross, and other recent additions to the Mineral Collections in the Kelvingrove Museum. By PETER MACNAIR, Keeper of the Natural History Collections in the Glasgow Museums, Assistant Lecturer on Geology in the Glasgow and West of Scotland Technical College, Joint-Hon. Secretary, Glasgow Geological Society.

[Read before the Society 27th April, 1904.]

THE exceedingly interesting, though somewhat puzzling pseudomorphs, which I bring before you were first discovered in the Clyde some five or six years ago, when specimens were presented to the Kelvingrove Museum by Mr Higgins. At the same time he gave specimens to the Hunterian Museum at the University, this being so far as I know the first definite record of these crystals from the Clyde. Since that time quite a large number have been found, and as certain specimens which have recently been added to the collection, through the kindness of Mr Gemmell, seem to throw additional light upon the origin of these pseudomorphs, I have ventured to bring them before the Society.

I have not yet been able to get any details regarding the finding of these crystals, so I am unable to speak with any degree of certainty upon this point, but it appears that they are dredged from the Clyde at a point nearly opposite Cardross, or between it and Helensburgh, this being the locality where the Greenock and Renfrew shipbuilders usually test the efficiency of their new dredgers, and it is during these operations that the pseudomorphs are found.

Though this is the first record that we have of the occurrence of these crystals in the Clyde or in Scotland, they are known from other localities; thus they were found in 1857 at the Jarrow Docks, Durham, where they occur embedded in calcareous clay. They were named Jarrowite, and Prof. Miers considered them to be pseudomorphs after celestite. Similar pseudomorphs have also been recorded both from the Continent and America, and their origin has been the subject of much discussion. Thus on the Continent specimens have been found at Obersdorf near

Sangerhausen, Thuringia, where according to Dana "they occur as complete crystals often in interpenetrating groups up to two inches or more in length, embedded in clay, their colour being pale yellow, the exterior usually smooth and hard, the interior cavernous, with loosely coherent grains. They were called natrocalcite on the idea that they contained soda." They have been referred to gaylussite by Breithaupt, to celestite by Haüys, to apotome by De Cloizeaux, to gypsum by Kengott, and to anhydrite by Groth. Dana, in the last edition of his system of Mineralogy, following the opinion of De Cloizeaux, says the recent discovery by G. H. Williams of celestite in pyramidal crystals, resembling closely the pseudomorphs, and occurring like them embedded in clay, makes it almost certain that De Cloizeaux's explanation was correct. He further adds that the apparently related forms from Lake Lahontan cannot however be explained in this way.

Turning now to an examination of the Clyde specimens, we find that they appear in every respect similar to those from Sangerhausen. In form they have the appearance of elongated prisms or acute pyramids, varying in size from 3 cm. up to 24 cm. In cross section they may be either quadratic or rhombic, and the angle may vary in one and the same crystal from 90° to 120°. The colour of the crystals is usually of a dark hematite brown with resinous lustre, and they are transparent only in thin splinters, with a yellow streak and powder. When knocked they give a clear ring. They show no cleavage, and the hardness is about 3. The faces of the crystals are seen to be covered with small triangular facets pointing from the edges towards the centre. A cross section, etched with acid, brings out both their zonal structure and porous appearance, thus showing most conclusively their pseudomorphic character.

Seen in transparent sections under the microscope, they present a clear transparent golden-brown colour, and appear to be built up of roughly alternating layers of fibrous spherulites and parallel layers of fibrous calcite, these layers being arranged parallel to the boundaries of the cross section. Dr Ch. O. Trechmann measured these layers and found them to vary from 0·115 to 0·230 mm. in thickness. The parallel-fibred layers seem to predominate towards the outside of the crystals, while towards the centre they appear to be composed entirely of small radial-fibred spherulites, which vary in size, the smallest being about 0·165 mm. in diameter. Between crossed nicols and in parallel polarized light, the spherulites exhibit the characteristic interference cross shown in such aggregates. Dr Trechmann has also found that the granules show a uniaxial interference cross which, with the help of the quarter undulation plate, showed the negative double refraction of calcite.

The manner in which these crystals are aggregated together presents considerable variety, thus in some instances an interpenetrating pair may form a perfectly symmetrical St Andrew's cross. Another and more common case of interpenetration is that in which one crystal may cut the other so as to form a figure something like the letter Y, see plate 1, fig. 1. A third form is that in which innumerable small crystals appear to be arranged round a central axis or core. In some cases the crystals are completely enclosed in nodules having the same general chemical composition as the crystals.

An analysis of the crystals from the Clyde, by Dr W. Pollard of the Jermyn Street Museum, London, gave the following values:—

CaO, - - - - - -	47·93	
MgO, - - - - -	4·21	
CO_2, - - - - - -	39·91	
P_2O_5, - - - - - -	2·23	
Loss at 105°, - - -	3·13	
Loss above 105° (ignition), -	2·81	= Water and Organic Matter.
Residue insoluble in dil. HCl,	·11	
Total,	100·33	

Traces of Iron, Manganese, Chlorine, and Sulphates are also found.

The following analysis extracted from a paper read to the Geological Society of Glasgow by Mr E. W. Gemmell, shows the comparative composition of the nodule and crystal:—

	NODULE.	CRYSTAL.
Calcium Carbonate, - - - - - -	44·02	77·89
Calcium Oxide, - - - - - - -	11·50	—
Calcium Sulphate, - - - - - -	3·33	0·52
Magnesium Carbonate, - - - -	10·75	7·88
Oxide of Iron, - - - - - - -	1·45	0·18
Alumina, - - - - - - - -	4·60	3·31
Silica, - - - - - - - -	18·40	0·26
Sodium Chloride, - - - - - -	0·11	1·35
Organic Matter, - - - - - -	2·25	8·51
Water, - - - - - - - -	3·50	—
	99·91	99·90

An analysis made by Professor Sexton at the Technical College gave the following values :—

Calcium Carbonate,	79·622
〃 Sulphate,	·919
〃 Chloride,	·157
〃 Phosphate,	3·384
Magnesium Carbonate,	8·927
Silica,	·376
Ferric Oxide,	·959
Alumina,	3·105
	97·449

Tests for Barium and Strontium gave negative results.

In the following table I have placed the carbonates and phosphates of the preceding analyses for comparison along with an analysis made by Dr C. O. Trechmann, from which it will be seen that the composition of the crystals varies, but, keeping in mind their pseudomorphic character, this is only what might be expected.

	Dr C. O. Trechmann.	Dr W. Pollard.	Prof. Sexton.	Mr E. W. Gemmell.
$Ca_3(PO_4)_2$,	5·52	4·87	3·38	—
$CaCo_3$,	83·52	80·88	79.62	77·89
$MgCo_3$,	9·03	8·28	8·93	7·88

The Specific Gravity = 2·67.

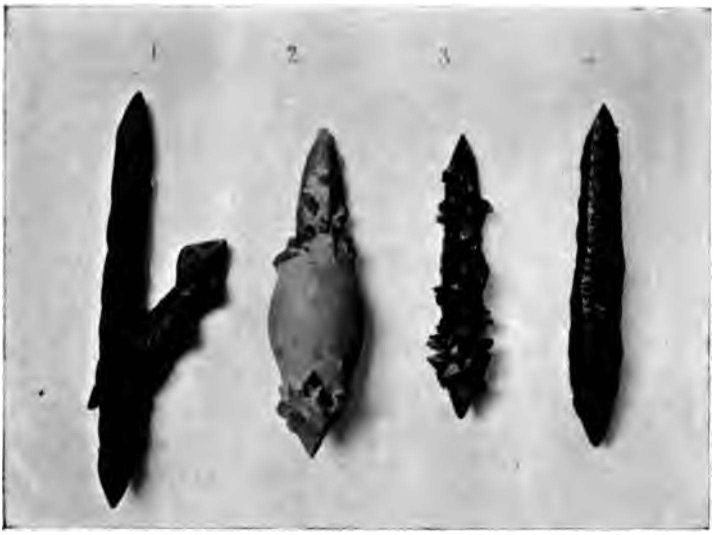
From what has been said, it will be seen that these crystals are undoubtedly of the nature of pseudomorphs replacing in carbonate of lime some pre-existing mineral, but as to what that was we do not find mineralogists in exact agreement, though they mostly seem to favour either celestite, which is a sulphate of strontia, and crystallises in the orthorhombic system, or gaylussite, which is a hydrated carbonate of lime and soda, and crystallises in the monoclinic system. As regards the crystalline habit of these minerals (the discovery already mentioned by G. H. Williams of celestite in bipyramids, the pyramids being extended parallel to the brachyaxis, and presenting rounded faces), their mode of occurrence in clay seems to indicate celestite as possibly the original mineral which these pseudomorphs now represent. It is, however, to be noted that both Dr W. Pollard and Professor Sexton applied tests for strontium and barium with negative results.

On the other hand the forms of gaylussite most nearly approaching these pseudomorphs are represented by the combination of the prism (110), and the clinodome (011). The common habit of gaylussite does not appear to answer so closely to the Clyde pseudomorphs as the forms of celestite. The mode of occurrence is, however, very similar. Gaylussite is found abundant at Lagunilla, near Merida in Venezuela, where its crystals are disseminated at the bottom of a small lake, in a bed of clay covering urao, the natives call them clavos, or nails, in allusion to their crystalline form. Gaylussite is a deposit from mineral waters, and is formed by the decomposition of salts of soda and lime combined with water.

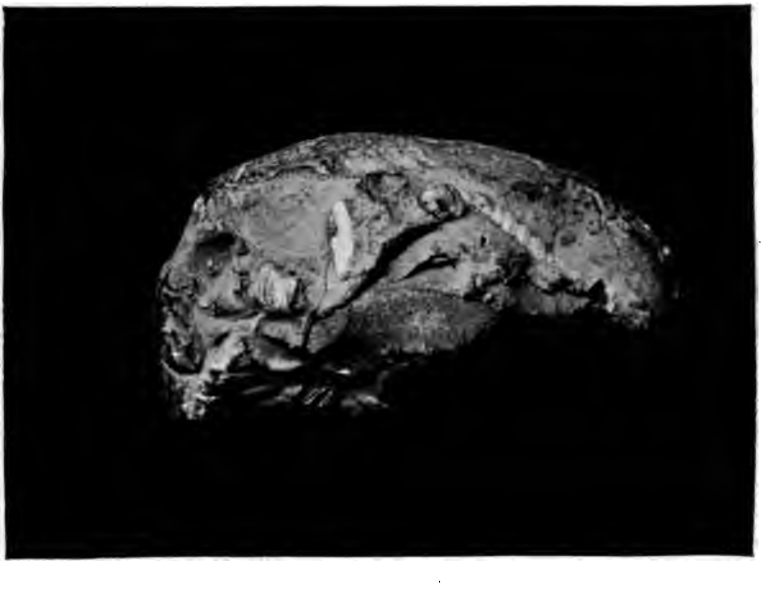
Passing now to a consideration of the mode of occurrence of these crystals in the Clyde, it seems to me that a good deal of light is thrown upon their origin and history by the specimens recently presented to the museum by Mr Gemmell. In previously questioning the persons who brought specimens to the museum, I was led to believe that the crystals were only to be found enclosed in nodules, and that in every case they had to be broken out of these nodules. I have, however, learned that this is not correct, and that a large number of specimens are dredged which show no evidence of having ever been enclosed in a nodule. In the two specimens presented by Mr Gemmell, the crystals are clearly seen enclosed in nodules of carbonate of lime, and a reference to the analysis already given will show that there is a close agreement between the composition of the nodule on the one hand and that of the crystal on the other, the only discrepancy being the large percentage of silica found in the nodule and not present in the crystal. The reason of this will be explained when we pass to consider the probable manner of replacement. In the crystal we have an increase in the carbonate of lime, sodium chloride, and organic matter.

But perhaps the most interesting feature in connection with these nodules is the incorporation in them of marine shells, and the remains of echinoderms, which clearly belong to the post-glacial clay beds of the Clyde. The most common shell in the nodules is *Turritella terebra*, Linn. The only other shell which can be identified is *Nucula tenuis*, Mont., which is a deep water shell often found in association with *Turritella terebra*, Linn., and not found living near the locality where these nodules were dredged. The remains of an echinoderm belonging to the *Echnoidæ* can also be seen in one of the nodules, the species has not yet been determined. All these shells are filled with clay in the manner so characteristic of those found in the clay beds, while a thin layer of clay is to be seen interposed between the shell and the enclosing nodule.

Proceedings of the Royal Philosophical Society of Glasgow, 1903-1904. *Vol. XXXV, Plate I.*

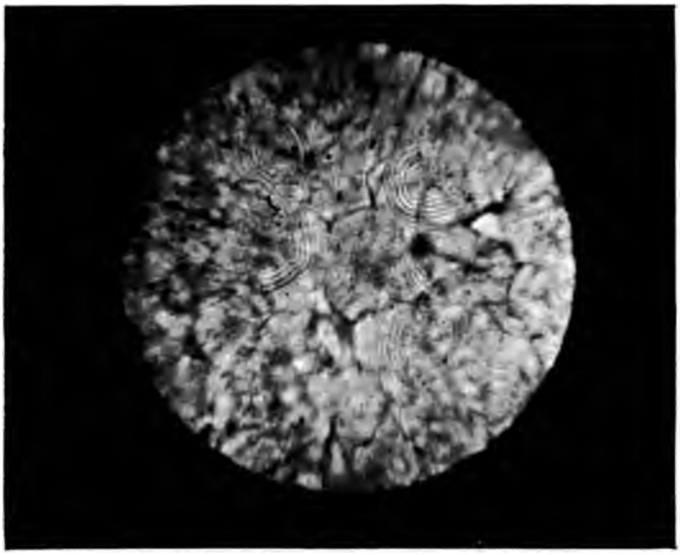


CRYSTALS OF PSEUDOGAYLUSSITE.

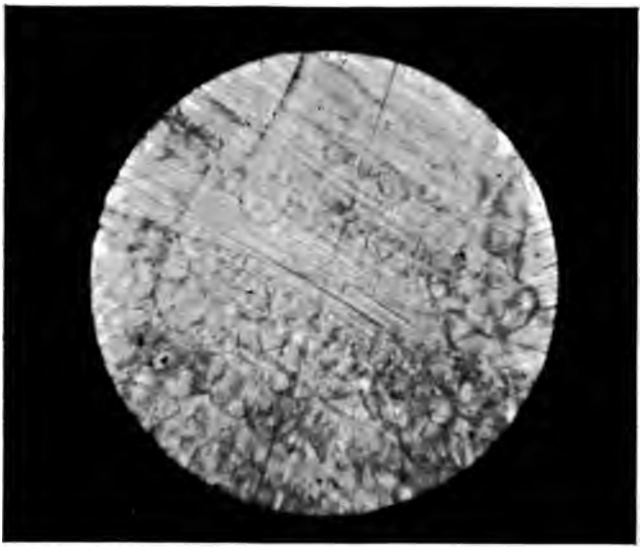


NODULE ENCLOSING PSEUDOGAYLUSSITE AND MARINE SHELLS.

From Photographs by J. F. King.



PSEUDOGAYLUSSITE SHOWING SPHERULITIC CALCITE × 180.



PSEUDOGAYLUSSITE SHOWING LAYERS OF CALCITE × 180.

From Photographs by P. Macnair.

The manner in which the shells and other organisms are aggregated together is so similar to the Post-Tertiary deposits at Garvel Park and Ardencapel as scarcely to leave a doubt in my mind that the nodules containing the crystals have been washed out of the glacial shell beds. This view seems to be confirmed by the occurrence of exactly the same kind of nodules in the Clyde near Bowling and Dumbarton. In 1878 Mr John Kirsop exhibited at a meeting of the Glasgow Geological Society a number of nodules which had been dredged from the Clyde below Bowling during deepening operations, amongst them were seggregations of sea shells cemented together by lime in a hard matrix of clay; portions of the vertebræ and caudal bones of a whale were also found at the same time. Mr Alstone, engineer to the Clyde Trust, has also shown me a large and fantastically shaped nodule crammed full of marine shells which was dredged from the bed of the Clyde some five years ago, opposite the mouth of the Leven at Dumbarton. Now, as no marine fauna exists so high up the Clyde as these localities at the present day, I conclude that these nodules with their enclosed marine organisms must have been washed from the Post-Glacial beds of the Clyde, and that both they and the Cardross specimens have had a common origin in the Post-Glacial clays.

The nodule belonging to Mr Alstone, and dredged at Dumbarton, differs from the specimens in the Kelvingrove museum inasmuch as instead of being composed entirely of carbonate of lime, it consists principally of grains of sand set in a matrix of carbonate of lime. Similar nodules were found in association with the crystals at Cardross, and are now preserved in the Hunterian Museum at Glasgow University. It is most likely that these nodules have been formed in more arenaceous portions of the clay beds, and the large amount of silica found in Mr Gemmell's analysis of the nodule may be accounted for in this manner.

It is well known that the whole of the Firth of Clyde is floored with these Post-Glacial deposits, which consist principally of accumulations of sands and clays charged with Arctic shells and other marine remains. They have been found at the following localities: Jordanhill, Paisley, Dalmuir, Renfrew, Dumbarton, Greenock, Helensburgh. "The clays are generally found cut away between low tide and high water mark, where the abrading power of the water is greatest. Examples may be seen at Langbank, Helensburgh, Roseneath, Fairlie, Cumbrae, etc. In these localities the truncated edges of the fossiliferous clays are exposed to view here and there in the more sheltered hollows along the tidal belt."[1]

The fact that these nodules and crystals have been washed out from the Post-Glacial clay beds seems effectually to dispose of the idea entertained by some that they are the products of the Clyde sewage, and are of comparatively recent origin, while it gives us a further insight into the history and origin of these puzzling pseudomorphs which I interpret as follows. The original mineral, most probably gaylussite, crystallised out in the glacial clay beds forming round and enclosing in some instances the shells embedded in the clay. The following experiments made by M. Fritzche, Alf. Favre, and Ch. Soret, may be cited as having some bearing upon the manner in which the original mineral of these pseudomorphs was formed. Gaylussite, bicarbonate of soda and of lime, was reproduced for the first time by M. Fritsche. The process consists of heating for a long time carbonate of lime freshly precipitated in a concentrated solution of soda. The same author obtained gaylussite equally well by heating a mixture of ten parts, in bulk, of a solution of carbonate of soda with one part of chloride of lime. M. Von Kokscharoff has estimated that the monoclinic crystals obtained are identical with those of the natural gaylussite. When the crystallisation is rapid the faces M, b½, d½ are noticeable. In a more extended solution crystallising slowly only the faces of the hemipyramids can be seen. Messrs Alph. Favre, and Soret reproduced gaylussite by putting carbonate of lime in a solution of silicate of soda combined with organic matter. The crystals obtained show the faces p, m, h^1, g^1, e^1, and b^1. The angles have been measured and are identical with those of the natural specimen; it should be noted that the face h^1 has not been observed in the latter.

Application to Geology. Gaylussite is a deposit from mineral waters. The combined solutions of salts of soda and of lime can, with water, give rise to it in nature.[2]

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[1] "The Post-Tertiary Fossiliferous Beds of Scotlands," by the Rev. Henry W. Crosskey, F.G.S., and Mr David Robertson, F.G.S., *Transactions*, Glasgow Geological Society, vol. IV., page 32, 1871.

[2] "Synthèse des Minéraux et des Roches," par F. Fouqué et Michel Lévy page 213.

The conditions obtained in the Post-Glacial clay beds just described would, I think, be entirely favourable to the crystallisation of gaylussite, as they would be crammed full of the remains of decaying organisms, with tests of carbonate of lime through which sea water could freely percolate.

From a consideration of the structure of these pseudomorphs I am inclined to think that the original mineral has become entirely dissolved away, leaving in the clay a hollow mould which has subsequently become filled from the outside inwards with carbonate of lime. This method of replacement is in accordance with the structure seen in etched specimens, and in thin sections; thus, as we have already observed, towards the outside the crystals mainly consist of alternating layers of spherulitic and parallel banded calcite running with the boundary faces, while towards the interior the spherulitic structure predominates. The pores also increase in size and number towards the interior of the crystal.

It seems highly probable that the formation of the nodules and the infilling of the hollow moulds of the original mineral were parts of one and the same process, and are to be accounted for by the percolation of water charged with carbonate of lime, through the clays, which first infilled the hollow moulds and formed the pseudomorphs, and then by a process of seggregation, formed the nodules surrounding and enclosing the pseudomorphs and shells. As a consequence of the disintegration of the clay beds by sea abrasion, the crystals, nodules, and glacial shells were loosened from their matrix, and spread over the bottom of the Firth where we now find them. A number of crystals show evidence of subsequent corrosion, the triangular facets having been worn, off, and the individual spherulites of calcite weathered out in relief. In conclusion it may be remarked that certain Post-Tertiary deposits in North America, known as the Leda Clays, contain similar nodules enclosing the remains of marine mollusca and fishes.

Below I give some references to the literature bearing upon the pseudomorphs.

E. J. J. Browell, Description and Analysis of an undescribed Mineral from Jarrow Slake. Transact. of the Tyneside Naturalists' Field Club, 1860-1862, 5, page 103.

G. A. Lebour, On Thinolite and Jarrowite, 57th Report, Brit. Assoc., 1887, page 700, 1888.

II. A. Miers, Some British Pseudomorphs: 3. Calcite after Celestine (?) from Durham. Min. Mag. 11, page 264.

J. L. Spencer, A list of new Mineral Names: Jarrowite. Ibid., 11, page 328.

J. D. Dana, System of Mineralogy, sixth edition, page 907.

Ch. O. Trechmann, Ueber einen Fund von ausgezeichneten Pseudogayluss't (=Thinolith=Jarrowit) Krystallen, *Zeitschrift für Krystallographie*, xxxv., 1901.

Summary of progress of the Geological Survey of the United Kingdom for 1901, page 89.

HORNBLENDE FROM THE UPPER ARGILLACEOUS ZONE OF THE HIGHLANDS.

A number of years ago, while going over the Glen collection of Minerals, I found a specimen of fine grained greywacke, which was quite evidently the same as that which is known to occur in the Upper Argillaceous Zone of the Crystalline Schists of the Highlands, and which is well exposed along the great axial line of folding lying to the north of Loch Tay. On the Upper Argillaceous Zone these beds of greywacke are found to alternate with thin beds of quartzite and phyllite. The most interesting feature in connection with this specimen of greywacke, is the presence in it of long needle-shaped crystals of hornblende, a mineral which I had not previously observed in the schists of the Upper Argillaceous Zone. Since that time, I have visited on several occasions the mountain known as Craig-na-Calleich, above Killin, and I have been successful in finding a number of specimens of greywacke showing crystals of hornblende similar to the specimen found in the museum. In Heddle's "Mineralogy of Scotland," hornblende, evidently of the same character, is recorded from the head of Glen Lochay between Craig Mhòr and Stob-na-Clach at the south end of the summit of the ridge, in lanceolate dark green crystals, in clay slate with andalusite. This is the only record which I can find regarding the occurrence of these crystals of hornblende, and the following description is given for the purpose of throwing some light upon their origin and mode of occurrence.

The hornblende, which is green in colour, occurs in long needle shaped crystals, the faces present being the prism (110) with traces of the clinopinacoid (010), the form of the crystals is determined by their elongation along the vertical axis. No terminal faces are present. The characteristic prismatic cleavage intersecting at an angle of 124° is well marked.

The pleochroism is very distinct, and is as follows:—

α = Pale brown.
β = Brownish-green.
γ = Bluish-green.

Andalusite in more or less well defined idiomorphic crystals, with prismatic habit, giving straight extinction, and with a moderately high refractive index, but showing no pleochroism, owing to the crystals being perfectly clear, occurs in association with the hornblende. A dark brown mica is also very plentiful, so that it seems most likely that these secondary minerals in the greywacke are the result of thermal metamorphism.

Near the summit of Craig-na-Calleich the clastic schists have been invaded by a large boss of intrusive epidiorite, and the contact metamorphism produced by the intrusion of this molten magma has undoubtedly been the direct cause which developed the hornblende, andalusite, and dark mica, in the greywackes. Large crystals of pyrite whose cube faces sometimes measure as much as three inches across, occur in the phyllites, while rutile is also common in the veinlets of quartz which are abundant in the phyllites. Whether the pyrite and rutile are also products of the thermo-metamorphism, or whether they are simply due to the intense dynamic metamorphism which has been superinduced upon these rocks, I have not yet been able to definitely determine. The crystals of hornblende and andalusite recorded by Dr. Heddle as having been found on Craig Mhòr near the head of Glen Lochay have most likely had a similar origin to those just described from Craig-na-Calleich, as at that point the same group of clastic schists have been invaded by intrusions of epidiorite.

PSEUDOMORPHS AFTER A PLAGIOCLASE FELSPAR FROM A SILL OF WHITE TRAP AT DREGHORN, AYRSHIRE.

These somewhat interesting pseudomorphs were recently presented to the museum by Mr. John Smith, Kilwinning, who found them some years ago. They have been described by Mr. J. G. Goodchild, F.G.S., in the *Transactions* of the Edinburgh Geological Society.[1] The pseudomorphs are evidently replacements of one of the lime-soda or plagioclase group of felspars. They occur as phenocrysts in an intrusive sill of white trap in which they can be traced in all stages of alteration from perfectly water-clear crystals to those which have become completely altered into kaolin. The alteration generally seems to have taken place from the outside inwards, and in some instances the crystals, when broken, present kernels of comparatively unaltered felspar.

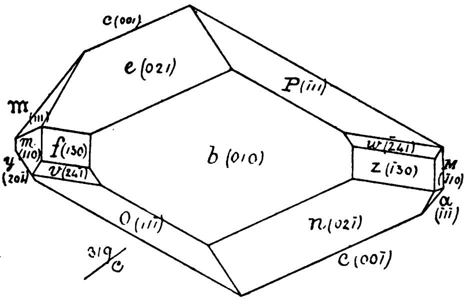

Fig. 1.

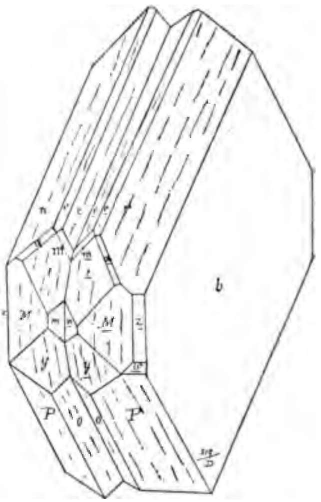

Fig. 2.

The unaltered crystals in thin sections under the microscope are seen to be set in a ground-mass consisting of little lath-shaped crystals of plagioclase felspar belonging to a later generation, which are again set in a matrix of greenish chloritic material representing the decomposed ferro-magnesian constituents of the rock. The large felspars exhibit zones of minute rounded inclusions of crystalline bodies with opaque centres, the exact nature of these I have not yet been able to determine. Even the freshest crystals are much cracked, and along these cracks the alteration processes have set in. In polarized light the felspars exhibit albite lamellation with which is also frequently associated twinning on the Carlsbad law. The extinction angles are high, indicating that the felspar belongs to the basic (or lime) end of the series.

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[1] *Transactions*, Edinburgh Geological Society. Vol. VIII, page 260.

The crystals which have been weathered out from the matrix present the following as the most prominent faces. The brachypinacoid (010). This is generally the largest face. The right and left brachydome (021) and $(0\bar{2}1)$ and the right and left negative unit hemipyramid $(\bar{1}11)$ and $(\bar{1}\bar{1}1)$. The crystals are thin parallel to the brachypinacoid, giving them a tabular appearance, while the presence of the other forms mentioned gives the crystals a characteristic rhomboidal outline. The other faces which are present, but which are not so well developed, have been determined by Mr Goodchild as follows :—The right unit prism (110) and its left analogue $(1\bar{1}0)$ are usually of small size. With these occur usually, (130) the right brachyprism, and $(1\bar{3}0)$ that on the left. The negative macrodome $(\bar{2}01)$ is present on several crystals as a small narrow face, as are also (201) and $(\bar{1}01)$. The same may be said of the basal pinacoid (001). The left negative brachypyramid $(\bar{2}\bar{4}1)$ and its analogue on the right $(\bar{2}41)$ are both present as small faces on several specimens; and lastly the right unit pyramid (111) and its analogous face on the left $(1\bar{1}1)$ are seen in several specimens.

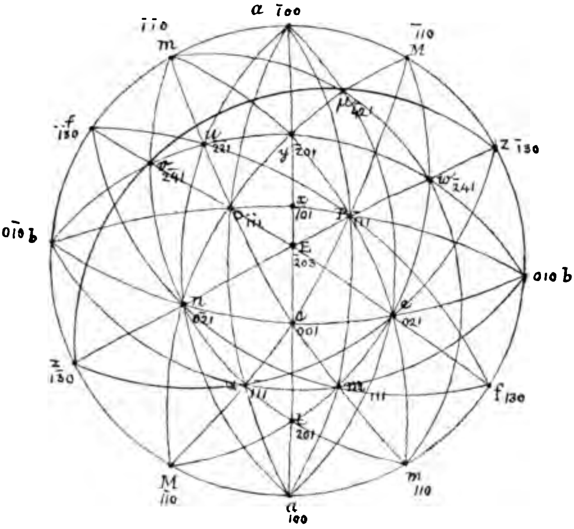

Fig. 3.

These crystals are exceedingly interesting, as Mr Goodchild has pointed out, inasmuch as the forms of labradorite do not appear to be accurately known.

Through the kindness of Mr. Goodchild and the Geological Society of Edinburgh, I have been enabled to use the blocks illustrating his paper on these pseudomorphs. Fig. 1 represents the right half of a twin projected orthographically on b (010); Fig. 2 is a clinographic representation of one end of a twin, while Fig. 3 is a stereogram showing the position of the poles of all the forms observed. It is projected on Z, which represents the vertical axis of reference, so that the prism faces in the projection all lie in the primitive.

Some Advances in Medical Science during the Nineteenth Century.

By ROBERT MUIR, M.D., Professor of Pathology in Glasgow University.

[Prepared by request of the Council and delivered before the Society, 9th March, 1904.]

IN no department of knowledge has advance during the nineteenth century been more striking than in that which bears directly upon the treatment of disease. Indeed, so far as the welfare and the happiness of the race are concerned, it may be claimed that the achievements in medical and surgical science occupy the first place. On reading standard treatises published about the beginning of the century, one cannot fail to be struck by the comparatively rudimentary condition of much of the knowledge. In medicine the influence of the methods of philosophical speculation still dominated, and the establishment of a consistent "system of medicine," in which "genera, species, and even varieties of disease" are distinguished, seems to have been regarded as of more importance than the accurate investigation of individual diseases. Miasma and contagium were recognised and distinguished, but nothing was known of the nature of either. The practice of medicine was almost entirely empirical, and methods then in vogue have been discarded as unneccessary or unjustifiable. Anæsthetics and antiseptics were unknown, and surgery was in the public mind only too justly associated with the horrors of pain and suffering. Anatomy was probably the department which had been worked out most fully, but physiology had little more than come into existence. Physiological treatises were largely occupied with details of structure, and the functions of the various organs, now a part of common knowledge, in great part belonged to the realm of the unknown. Pathology, or the scientific study of disease, had practically no recognition, whilst the birth of bacteriology was many years off in the future. It is quite impossible even to sketch the advances which have been made in these various departments. I shall only endeavour to narrate what has been done in one branch, namely, that concerned with the nature of disease, more especially of infective disease. And this selection does not need any justification, for it will be generally admitted that it is this branch which has yielded the most valuable results to medicine and surgery. In attempting to do this I cannot, however, undertake to refer to all the important advances which have been made, or to give due recognition to the labours of the various distinguished workers. I can merely trace the various stages in the growth of knowledge in this department, and I shall endeavour to do so in language which can be understood by those who are not medical experts.

In the first half of the century we see a continuation of former methods, and although numerous discoveries of importance were made, there was nothing to foreshadow the new era which was to follow. In the earlier years of the second half the new principles and methods, which were essential to progress, were being evolved, and the practical results which have followed from these have exceeded in value all those that have gone before. In considering this subject, it is well to have before us two main objects, viz., the patient and the disease, or in the case of infective disease, the subject of infection and the infective agent. A scientific knowledge of both is essential, and this means a proper understanding of the structure of the human body and of the micro-organisms which invade it. It will be shown how the conflict between the disease and the individual came to be regarded as one between bacteria and the cells of the body, and later still as one between the poisonous products of the bacteria and various defensive substances produced by the cells.

Any condition of disease is usually manifested in two ways, viz., by disturbance of function and by alterations in structure, the former being to a large extent manifested by symptoms, the latter comprising all the various changes which can be studied by physical methods—microscopic, chemical, etc. It is manifest that the study of the latter is essential to a scientific understanding of the problems of medicine and surgery. We must know, that is, the nature of the disorder of the body mechanism ; we can then search for the cause of the disorder. Medicine in its earlier history is chiefly occupied with symptomatology, and even in the earlier part of the nineteenth century, the grosser structural alterations underlying disease did not receive the attention which might have been given to them. One great bar to progress was due to the fact that a scientific conception of the constitution of the body in its normal state was wanting. How are its tissues built up and how are its functions carried on? To these questions no satisfactory answers could be given. Many who are familiar with the fundamental principles of biology may probably be surprised to know that in the earlier years of the century, the significance of the animal and vegetable cells as living units was quite unknown. One may say that the transition from the old to the new state of knowledge starts from studies on the cell. That central body or *nucleus* in the cell, which plays an all-important part in the process of cell-multiplication, was first described by an English botanist, R. Brown, in 1833, but the most important investigations in laying the foundations of modern cytology are those of Schleiden (1838) and Schwann (1839). The former gave a valuable account of the cell and its functions so far as the vegetable kingdom was concerned, and his work constituted a real advance. This was followed shortly afterwards by the still more important work of Schwann, in which he pointed out the essential similarity in plan of structure of vegetable and animal tissues and the dependence of both on cells as living units. He described the characters of the cells in various tissues, and also at different periods of development, and shewed the part played by cellular activity. But his views regarding the origin of the cells themselves are now known to be erroneous. He held that cells were formed in an intercellular ground substance or *cytoblastema* as it was called, which was supposed to be derived from the blood. In this apparently homogeneous substance, according to his view, there appeared granules which arranged themselves to form the cytoblast or nucleus and then around this structure and by its activity the cell-body was formed. In other cases new cells might be produced in the interior of a pre-existing cell. No doubt Schwann regarded the cytoblastema as a sort of living substance, but so far as the cells as units were concerned, his view really implied a kind of spontaneous generation. It will be readily understood, that, if cells appeared in this way from an unknown background, as it were, there was little hope of reaching a rational explanation of the important cellular changes met with in disease. What profit to discuss "primary changes in the blastema"—the structureless substance out of which cells were supposed to be formed—if these changes were incapable of recognition. The outlook was, however, quite changed on the appearance of Virchow's epoch-making work on

Cellular Pathology, which was published in 1858. In this was enunciated the famous dictum, *omnis cellula e cellulâ*—there is no such thing as a new formation of cells in a blastema, all cells are produced by the division of pre-existing cells, each cell is the direct descendant of another. All the structures of the body result from the proliferation and differentiation of cells, all functions are due to their special activities, and so in disease all disturbances of function, and all changes in structure are to be referred back to cells as living individuals. The cells of a tumour or new growth, to take an example, are not formed *de novo* out of a structureless something, but are the descendants of the cells of the body. This view of organised beings constitutes the essence of modern biological science, and has become so much a part of common knowledge, that we are apt to overlook how comparatively recent it is. It would lead me too far into technical matters were I to mention Virchow's various contributions to pathology and medical science. It is sufficient to state that he carried his researches into nearly every morbid condition, and furnished results which have established pathology as a science. Since the publication of his work advance has been rapid and sure, and while new methods are constantly giving us further insight into the structural changes underlying disease, the important principles which he formulated have remained unshaken. The disturbances of structure and function observed in the body in disease may however be known, but what, it may be urged, are the agencies which produce these disturbances? Do the cells become abnormal of themselves, or is something introduced from without? In many diseases we see a disturbance of the bodily functions, commencing suddenly or gradually, increasing in intensity, and then subsiding or leading to a fatal result. Can these phenomena be explained as the result of cellular activity? In giving an answer to this question the work of Pasteur takes the first place. Virchow showed how the results of disease should be studied and interpreted, but to Pasteur more than to anyone, we owe our knowledge of its causation.

There is no more interesting chapter in the history of science than that comprising the life and work of Pasteur. No one has worked in so many different fields with more brilliant success, and no one has yielded results of more far-reaching benefit to humanity. As is well known his earliest work was in the domain of pure chemistry, and I shall only state regarding it sufficient to indicate the manner in which he was led from matters of chemical constitution to the problems of vital phenomena. His first research, published when he was little over twenty years of age, was in crystallography and concerned the tartrates. He showed that the paratartrates, which had been brought forward by Mitscherlich, and which apparently were optically inactive, were really a mixture of right-handed and left-handed tartrates. On the paratartrates being crystalised out he found that there were really two kinds of crystals, the small facets on which were arranged in opposite directions—in other words the two kinds were the mirror images of each other. This was the explanation of the inactivity of the paratartrates. Other researches on the same lines followed, and he formed the opinion that this dissymetry of molecules was a characteristic of the organic kingdom. A natural sequence was the study of vital processes in relation to such crystalline substances. He found, for example, that when a form of mould, the *penicillium glaucum*, was grown in a solution of paratartrates, the right-handed tartrates were used up while the left-handed remained. And it was in the course of such researches that he came to observe chemical changes to be associated with the growth of lowly organisms. Partly as the direct outcome of this work and partly owing to the circumstance of his being appointed in 1854 Dean of the Faculty of Science in Lisle, where the manufacture of alcohol was an important industry, his investigations became definitely concerned with the subject of fermentation. At that time ferments were believed to be dead substances. According to Liebig's view, which received general acceptance, a ferment was a nitrogenous substance in a state of decomposition started by the oxygen of the air, and possessed the power of communicating the molecular movements of decomposition to other organic substances. Others again spoke of ferments as albuminoid substances which acted by contact, taking nothing from and adding nothing to the substances on which they acted. Nevertheless certain facts had been observed which pointed in another direction. The yeast fungus had been previously described by Kutzing and Schwann in Germany, and by Cagniard-Latour in France, and had been recognised as a living organism capable of reproducing itself by budding; and Schwann in particular considered that it nourished itself on the sugar, rejecting as alcohol what it could not use. But such observations had not been followed up and no definite result had been obtained. Pasteur soon came to the conclusion that fermentation is a vital phenomenon, and proved by the most striking and convincing methods that separate micro-organisms are concerned in lactic, alcoholic, and butyric fermentations. Using specially prepared media which contained only the fermentable substance along with various inorganic substances, he showed how fermentation could occur without albuminoid material, how the presence of a living organism was essential, and how the nitrogen of ammonia became used up to form the protoplasm of the living cells. Processes of nutrition are thus concerned in the process; even in alcoholic fermentation the result cannot be expressed as a simple chemical equation, other substances such as glycerine and succinic acid being also formed. He also distinguished aerobic and anaerobic organisms—those which grow in the presence and those which grow in the absence of oxygen, and showed that as a rule the more free oxygen is present the less is the amount of fermentation produced by an organism. He showed also how one form of fermentation might become succeeded by another, and even how one form of living ferment might become decomposed by another—how, for example, the yeast fungus after its powers of multiplication were exhausted, might become food stuff for various bacteria. The important rôle played by micro-organisms in the decomposition of organic matter was thus established. So far as the etiology of disease is concerned the all-important result established by Pasteur was the dependence of the production of definite chemical changes on the growth of different living organisms, and the practically indefinite amount of such change, given favourable conditions. We have here, therefore, a foreshadowing of the analogous processes which have since been established in the case of infective diseases. Pasteur's views have in certain cases been modified in this way, viz., that it is now known that some of the chemical changes are not produced directly by the living organism, but indirectly by an enzyme formed by the organism. Thus, for example, there has recently been separated from the yeast cells a non-living enzyme which produces alcohol from sugar. Still none of these results affect the chief conclusions which he arrived at.

Further researches of Pasteur on acetic fermentation, on the diseases of wine and beer, etc., need not be referred to, as they imply an application of the same methods. A short notice must, however, be given to the subject of spontaneous generation, as it bears directly on the origin of disease. During the years 1860 65 it may be said to have been the burning question of the day. Up till that time the belief commonly held was that putrefaction and like changes were started by the oxygen of the air, and the various micro-organisms afterwards present were formed *de novo*. It had been shown before that organic fluids sufficiently heated remained sterile, but it was objected that the "vegetative force" in the air in contact had been stopped. It had also been found by various observers that air passed through sulphuric acid, through fusible metal, and even through cotton-wool, might fail to produce putrefaction. But such experiments in the hands of others often failed, and the dogma of "spontaneous generation" was one which in the minds of many must be preserved at all costs. Pasteur soon convinced himself that the germs of putrefaction were in the air; it was quite another matter to convince others, in fact some of his opponents were never convinced, and on reading the account of his researches one cannot but regret that so much of his time was expended on the subject. Of his many ingenious experiments, one may be described. A flask was prepared with a long curved neck open at the end, a putrescible fluid was placed in the flask and was boiled for a considerable period of time; a small piece of cotton wool was then placed in the neck, but out of contact with the fluid. The contents remained sterile though the oxygen of the air had free entrance. The flask was then tilted so that a part of the fluid touched the cotton wool, and putrefaction rapidly followed. He also filtered quantities of air through gun-cotton, then dissolved the latter in ether, and showed by means of the microscope the organisms which had been filtered out of the air. By these and other experiments he demonstrated that it was not the air itself but the numerous bacteria and other organisms in the air which produce putrefaction and that if no living organisms are admitted, none appear in organic fluids. It is thus seen how by the accurate study of the changes produced in the body by disease on the one hand, and of the living causes of fermentative changes on the other, the way was prepared for discoveries in the domain of infective diseases. Several years, however, elapsed before the fruits of such researches were obtained.

We come now to the consideration of the first important practical application of Pasteur's results, namely, the system of *antiseptic surgery* introduced by Lister. It is difficult to state precisely how much Lister owed his conception of antiseptic method's to Pasteur's work, and whether without the latter the establishment of the antiseptic system would have been long delayed. Lister had come to the conclusion by inductive methods that putrefaction in wounds was in some way related to the air, and in his first publication he mentions that he had been struck by the published statement that carbolic acid had been applied to the sewage of Carlisle and had a marked effect in diminishing the amount of putrefaction and the growth of animal organisms. It is therefore quite possible that even without a knowledge of the nature of putrefaction he might have applied carbolic acid in the treatment of wounds. Be this as it may, however, he gives in his first paper (1867) due prominence to Pasteur's researches and uses them as the scientific foundation of his new system. The following quotation from this paper may be of interest in this connection. "Turning now to the question how the atmosphere produces decomposition of organic substances, we find that a flood of light has been thrown upon this most important subject by the philosophic researches of M. Pasteur, who has demonstrated by thoroughly convincing evidence, that it is not to its oxygen, or to any of its gaseous constituents that the air owes this property but to minute particles suspended in it, which are the various low forms long since revealed by the microscope and regarded as accidental concomitants of putrescence, but now shown by Pasteur to be its essential cause, resolving the complex organic compounds into substances of simpler chemical constitution, just as the yeast-plant converts sugar into alcohol and carbonic acid." As an illustration of the nature of Lister's system I may take the surgical condition to which his methods were first applied, namely the compound fracture of bone. I may explain that a compound fracture is one in which there is at the same time a breach of the skin surface so that a communication is established between the lacerated tissues on the one hand, and the skin surface and outer air on the other; whereas in the case of a simple fracture there is no such communication. In the former case putrefaction and suppuration were the common sequels, portions of the bone often died, and if healing occurred it was only after a prolonged illness, often with permanent deformity as the result; in many cases recourse had to be taken to amputation. With the simple fracture on the other hand these untoward events did not occur, and a comparatively rapid union of the fragments was the usual result. Why this difference? That was the question which presented itself to Lister's mind. Putrefaction is the evil, why not prevent putrefaction? Pasteur's results had made this question—Why not kill the micro-organisms which cause it? Carbolic acid was the agent which Lister first used, and it is a striking fact that it is still one of the most widely employed antiseptics; in fact we have not yet got a substance which can be said to surpass it in its general suitability. The results of Lister's experiments were of a highly satisfactory nature—at that time of a marvellous nature—and the series of cases which he published completely established the correctness of his principles. It was a mere matter of time and further investigation to extend them to every department of surgery. If a wound has become septic the endeavour must be to diminish or abolish the sepsis; if a fresh wound is made, it must be prevented from becoming septic. The theory was sufficiently simple, but the attainment of these ends required the most careful attention at every stage of the operation. How may the wound be best protected from the irritating action of the antiseptic? How may the bacteria of the air be prevented from entering the wound? What are the best forms of dressings, and how may putrefaction be prevented from occurring in the discharges and spreading to the wound? What is the best means of draining the wound? All these problems were carefully worked out by Lister. In few men has the grasp of scientific principles been combined with so full an appreciation of the importance of the details of method and so rich an inventive skill in meeting requirements. Lister elaborated his system as if he were determined to make it certain of success in the hands of others.

With the use of antiseptic methods, parts of the body which it was formerly considered unjustifiable to interfere with, came to be opened with safety; operations on bones and joints, on veins, etc., formerly attended with great risk, could be performed in safety, and the scourges of hospital wards, erysipelas, gangrene, and blood-poisoning, diminished also to the disappearing point. I may refer to one particular accident of common occurrence, namely, secondary hæmorrhage. Under the old system when larger arteries were tied, the ligatures were left long, and the ends brought out in the external wound; suppuration occurred and the ligatures ate their way through the vessel wall and thus were separated. As may be imagined, not infrequently the vessel gave way during the process and serious hæmorrhage resulted. Lister introduced absorbable antiseptic ligatures. These were made of catgut impregnated with antiseptic, and he showed how they were gradually absorbed by the cells of the tissues and disappeared—no suppuration, no separation of the ligature, and no secondary hæmorrhage. This absorption of the ligature is an example of a digestive power which the cells of the body can exert on certain foreign substances—an example of phagocytosis to which I shall make further reference below. But even if a foreign body is not absorbable, provided that bacteria are not present with it, it may remain for years without doing any harm, the cells form a layer of tissue round it, or, as the common expression is, it becomes encapsulated. The more we study the behaviour of the tissues under abnormal conditions, the more are we struck by their wonderful adaptations for dealing with foreign substances dead or living. The benefits of Lister's system were of the most striking character, and were soon recognised by others. Two years after his first publication he was able to say that his wards in the Glasgow Royal Infirmary, once amongst the most unhealthy in the kingdom, had been converted into models of healthiness, simply as the result of antiseptic treatment, and later still, after he had been two years in Edinburgh he could announce that there had not been a single case of pyaemia—(blood-poisoning) in his wards there. Since that time his methods have been further developed and improved, but the essence of the system remains the same.

Within recent times we have seen the development of what is known as *aseptic surgery*, and I may briefly explain what this means. The object here aimed at is to bring no chemical antiseptic in contact with the wound and yet have it kept in an aseptic condition. Everything to be used at the operation is previously sterilised by heat, and the dressings, instead of containing antiseptics, are sterilised in the same way. . Manifestly however, in sterilising the skin where the operation wound is to be made antiseptics must be employed. The rationale of the method is that every antiseptic acts more or less as an irritant to the tissue cells, and thus to an extent interferes with healing. We as yet know of no chemical substance which is at the same time germicidal and without harmful effect on the living cells of the body. Another fact underlying the aseptic system is that the healthy cells of the body have the power of destroying a considerable number of bacteria especially if these, as most of the atmospheric germs are, are of comparatively innocuous nature; accordingly if a few fall into the wound, as must always be the case, they are rapidly killed and no harm results. It would be out of place to discuss here the relative merits of the antiseptic and aseptic methods—the principle, be it noted, is in essence the same in both. It will be sufficient to mention, what is in fact quite evident, that the antiseptic system requires a less elaborate technique, and is thus more easily carried out in general practice. On the other hand the aseptic system possesses certain distinct advantages, as evidenced by the rapidity of healing and the absence of discharge from the wound. In fact it is quite a common practice in many instances not to dress the wound at all until healing is complete. And it is under the aseptic system that many of the most remarkable results in abdominal and cranial surgery have been obtained. Before leaving this subject it may be well to point out that modern surgery in attaining its wonderful results has been aided in certain other ways. I need scarcely mention the subject of anæsthetics first brought into general application by Simpson's discovery of the properties of chloroform in 1847, as everyone knows not only the direct benefits which have followed, but also those arising from the fact that the field of the surgeon's work has been greatly extended. I wish, however, to refer to help received by surgery both from experimental physiology and from surgical pathology. By the former, information has been supplied as to the function of the brain and the other parts of the nervous system, in short, of all the organs of the body, and thus both the means of diagnosis has been greatly extended and also important guides as to what can be done with safety have been supplied. Surgical pathology has explained the nature of the processes of disease which the surgeon has to deal with, has shown how the disease is produced, and has given in many instances valuable methods of diagnosis; it has made surgical procedure rational and scientific. Such are some of the steps by which advance in surgery has been made—an advance which perhaps more than anything else distinguishes the world of to-day from that of forty years ago.

Whilst Lister was elaborating his antiseptic system Pasteur was carrying out his researches on the diseases of silk-worms (1865-70). These researches are of importance because they were the first to establish the relation of a micro-parasite to a disease, and also because they established certain of the laws of infection in general. He investigated two diseases, one, the better known called *pébrine*, and the other *flacherie* or *morts-flats*. In the case of the former he found in the tissues of the diseased moths certain highly refracting bodies or corpuscles, which had however been previously observed and described, and, although at first he considered them to be evidences rather of a constitutional tendency than true parasities, he ultimately proved that the latter was their real nature. He further showed how diseased moths transmitted the corpuscles to their eggs, and thus he devised his method of dealing with the disease. This method consisted in examining the bodies of all the moths for corpuscles after they had laid their eggs, and destroying all the eggs from moths in which corpuscles were found. In this way only eggs free from the parasite were preserved for the young broods. Pébrine is thus a hereditary disease in the sense that the parasite itself is transmitted from the female parent to the offspring. Pasteur by his researches saved the silk-worm industry of France though he did not entirely eradicate the disease as he anticipated. In the case of flacherie he shewed the cause to be the presence of a number of micro-organisms in the alimentary canal, and found that the disease itself was not transmitted to the offspring but the tendency to it was the result of hereditary transmission. In these two diseases we accordingly find exemplified the transmission to the offspring of a disease itself and of a predisposition only.

The organism of pébrine is not a bacterium but a protozoon, and in the case of flacherie one specific organism was not identified. The first bacterium to be conclusively shown to be the cause of a special disease was the anthrax bacillus. This organism had been observed in the blood of animals suffering from the disease, as far back as 1849 by Pollender, and its causal relationship had almost been established by the work of Davaine, Pasteur, and others. The complete proof was, however, furnished in 1876 by Koch, who obtained pure cultures of the bacillus and reproduced the disease by inoculation. He also studied the process of spore-formation, a phenomenon of great importance in connection with the propagation of the disease, as spores represent a state of the organism in which it possesses great powers of resistance to destructive agencies, and in which it can lie dormant for a long period of time, again to take on active growth when favourable conditions arise. I may here mention that although in natural conditions anthrax is a disease affecting certain animals, especially oxen and sheep, it also affects the human subject, and the most rapidly fatal form, that known as "woolsorters' disease," is produced by inhalation of anthrax spores, which may persist for a long time on wool and hides. The anthrax bacillus is one of the largest of disease-producing bacteria, and has been of great service in the working out of the biology of bacteria and their spores. The next important event was the introduction of solid culture media and the "plate method" by Koch about 1880. Let me briefly explain what these mean. Up till this time bacteria had been grown in sterile fluids protected from contamination by the organisms of the air. In such media a bacterium by its growth as a rule produces merely a general turbidity or haziness; there is nothing to distinguish the growths of different organisms. Furthermore, if another bacterium gains access, or in other words, if the culture becomes "impure," there may be no change in its appearance to indicate that this has occurred; the impurity can only be detected by microscopic examination, and not always even by this method. Koch introduced gelatinised or solid media. To speak generally, these consist of a watery extract of meat rendered solid by the addition of gelatine or agar-agar, and brought to the requisite degree of alkalinity. The substance agar-agar is obtained from a moss in the Chinese seas, and it has the advantage of remaining solid at the temperature of the body, at which the gelatine media become liquid. On such media the various bacteria often produce characteristic appearances which are of great service in their identification, and if any bacterium as an impurity gains access to a pure culture, this is generally evidenced by the appearance of a growth of different character. The recognition of bacteria was thus greatly aided, and the maintenance of pure cultures was much simplified. Koch also applied his solid media to the *separation* of different organisms when they are present together in a mixture. The principle of this "plate method" is that each bacterium by its growth produces a colony which usually becomes visible to the naked eye, and if the mixture is sufficiently dilute the colonies will be sufficiently far apart to enable one to touch any required colony with a sterile platinum wire and then inoculate a fresh tube of culture medium; a pure culture of that bacterium is thus obtained. In applying the method the bacterial mixture is diluted down in a series of tubes containing gelatine or agar liquefied by heat, and the contents of the several tubes are poured out on glass plates or dishes and allowed to solidify. The colonies of the individual bacteria are then allowed to develop, being protected meanwhile from contamination. The plate method also supplies the means of counting the number of bacteria present in a fluid, say drinking water, as can readily be understood.

In the decade following the introduction of these media, advance in bacteriology was phenomenally rapid; in fact, in this period, most of the pathogenic bacteria were discovered. I must not omit to mention that such research was greatly aided by the application of aniline dyes as staining agents for the bacteria. These substances are salts, and it is the base which has a peculiar affinity for the bacterial protoplasm, staining it so deeply that the organisms can be readily recognised. I can refer only briefly to some of the organisms discovered at this time. Spherical bacteria or cocci were found in abcesses and allied conditions, and Ogston of Aberdeen did important work on this subject, distinguishing those which grew in clumps *staphylococci*, and those which grew in chains, *streptococci*. When Lister introduced his system it was believed that unopened abcesses containing odourless pus—in contrast to those with manifest putrefaction—were germ-free, but we now know that practically all suppurations and many other inflammations are due to the presence of these minute micrococci and other organisms. Different species of pus-producing organisms were obtained in pure culture by Rosenbach and by Passet a year or two later, and since that time the number has been considerably added to. In 1882, Koch announced his discovery of the tubercle bacillus, and this event is of so great importance that to it special reference must be made. Shortly before Koch's discovery it had been practically demonstrated, notably by the experiments of Cohnheim and Salamonsen that tuberculosis is an infective and communicable disease, and not the expression of a mere constitutional peculiarity. Of the nature of the *contagium vivum*, however, absolutely nothing was known. The steps of Koch's work may be said to be three in number; he demonstrated the presence of a bacillus in the tubercular tissues, he cultivated this organism on artificial media, and he produced the disease with the pure cultures by various means of inoculation. The attainment of the two first of these was attended with special difficulty, and necessitated the invention of special methods. No organism could be shown by the stains then in use, and it was only after applying for a long time a stain specially prepared, that he was able to demonstrate the tubercle bacillus. Then again, no growth could be obtained on any of the gelatine or agar media. A special medium had to be prepared, and Koch, reasoning by analogy that the best medium would be one composed of the natural fluids of the body, introduced the method of sterilising and solidifying blood serum. On this medium growth appeared after incubation for fourteen days at the temperature of the body. The difficulties in solving this problem were thus great, but were all successfully overcome, and Koch's work on this subject both as regards accuracy and as regards completeness, has been rarely equalled in the history of medical science. Many details regarding the tubercle bacillus were subsequently supplied both by Koch himself and by others, but all the most important facts may be said to have been established in his first paper. Within a few years after this epoch-making work most of the bacteria which produce disease in the human subject were identified and cultivated. We may mention the chief of these, the glanders bacillus, cultivated by Löffler and Schutz (1882), the typhoid bacillus described by Eberth and afterwards cultivated by Gaffky (1884), the spirillum of cholera cultivated by Koch (1884), the micrococcus of pneumonia established as the cause of the disease by the researches of Weichselbaum and of Fraenkel, the bacillus of diphtheria cultivated by Löffler (1884) the micrococcus of Malta fever discovered by Bruce (1887), the bacillus of lockjaw or tetanus, cultivated by Kitasato (1889). A little later we have as the chief events the discovery of the bacillus of influenza by Pfeiffer (1892), the bacillus of plague by Kitasato and Yersin (1894), and the bacillus of acute dysentery by Shiga (1898). These discoveries supplied to us most important information regarding the several diseases, and each in turn has widened and enlarged our knowledge regarding infection in general.

The most outstanding event towards the close of the century is probably the discovery of the life history of the parasite of malaria in the mosquito, first established by the researches of Major Ross in 1898. Manson had some years previously demonstrated the part played by the mosquito in the dissemination of filarial disease, and by analogy had become convinced that this insect was also concerned in the spread of malaria. And it should be noticed that Ross's discovery was no casual one, but was the direct result of an attempt either to verify or disprove Manson's hypothesis. Ross found certain pigment-containing bodies in the wall of the stomach in a species of mosquito (Anopheles) which had been fed on the blood of a malarial patient, and believed these bodies to represent stages of development of the parasite in the mosquito. He afterwards confirmed this discovery in an exactly analogous disease of birds produced by a parasite of similar nature to the parasite of malaria, and succeeded in working out the whole life history of this organism. Practically similar results were subsequently obtained in the case of the different species of malarial parasites, by Grassi and other Italian observers. So many able workers joined in the researches on this subject that within a short time the part played by mosquitoes has apparently been almost completely elucidated. And as a further outcome of this work we have seen in the opening years of the twentieth century another highly important discovery on the same lines, namely that of the part played by another species of mosquito in the dissemination of yellow fever.

Unfortunately time does not permit us to go further into these matters, but before leaving the subject we may enquire what have been the practical benefits from these discoveries. Has the practice of medicine advanced in a way at all comparable with the practice of surgery? Undoubtedly each advance in the knowledge of a disease has not always brought with it a means of prevention or successful treatment; nevertheless progress has been sufficiently striking. In the first place it may be pointed out that the preventive medicine of to-day has for its foundation bacteriology and parasitology, and thus the knowledge of the nature of the germ which produces the disease, of its life history outside the body, of the paths by which it enters the body, and of its powers of resistance, is the necessary preliminary to taking practical steps for the prevention of the disease. This fact is well exemplified in the case of such diseases as tuberculosis, cholera, typhoid, malaria, etc. But in addition to this aspect of preventive medicine—which in reality is the counterpart of aseptic surgery, as in both cases the object aimed at is to prevent the disease-producing germs from entering the tissues—definite therapeutical measures both preventive and curative have been obtained. These concern the subject of immunity, and I shall endeavour to make clear the principles on which they depend.

In the first place we have the methods of *preventive inocula-*

tion which may be said to be still in process of development. The fundamental principle involved has been long established by clinical observation, viz., that in the case of certain diseases when a patient passes through an attack, he may enjoy practically complete immunity against subsequent attacks. Hence comes the idea of giving a mild attack of the disease. This is seen in the case of vaccination against smallpox, as it has been satisfactorily established that the virus of vaccinia is merely the virus of smallpox which has had its virulence modified by sojourn in the tissues of the bovine species. We now know that what produces the immunity is not the disease *per se*, but certain chemical substances formed by the bacterium causing the disease; these act on the tissues and immunity results as a sort of re-action. And although the earliest work on this subject was carried out by attenuating the virulence of the living organisms, the method of injecting the bacteria in the dead condition is now being used to a considerable extent. Many of the earlier experiments were performed with the anthrax bacillus—an organism which is rather exceptional in the persistence with which it maintains its virulence. The question was—how can the virulence be modified so that it no longer produces a fatal disease in a susceptible animal? Pasteur succeeded in doing this by growing the bacillus at a somewhat high temperature, namely 42·5°C. He found that the virulence fell more and more as time went on, and that a culture of twenty-four days' growth could be quite safely injected into sheep. Such a culture was called the *premier vaccin*, while the *deuxième vaccin* was one which had been grown at the abnormal temperature for only twelve days, and was thus less weakened. In immunising an animal the *premier vaccin* is injected first, and the *deuxième vaccin* is injected about twelve days later; the animal is then able to withstand inoculation with the virulent bacillus, and is also proof against natural infection. The method was publicly put to the test on a sufficiently large scale at Melun in 1881. Of fifty sheep one half were treated by Pasteur's method, the other half were not treated; all were then inoculated with virulent anthrax, and two days later all the treated animals were alive and well, while of these not treated twenty-one were dead. Since that time vaccination against anthrax has been carried out on a very extensive scale with beneficial results, especially in France where the disease used to be very widespread and virulent. As will be readily understood, great care must be used in applying it, as improperly prepared vaccines may kill the animals instead of protecting them. The saving of cattle and sheep effected in France alone is however recognised to be enormous. The methods of preventive inoculation must manifestly be carried out before the symptoms of a disease appear; inoculation afterwards would mean simply an increase of the poisoning. Usually they are also quite ineffective after infection has occurred. In hydrophobia, however, we have a disease in which the period of incubation is so long (usually several weeks) as to allow of protective treatment to be satisfactorily undertaken. Pasteur's work on this subject is certainly one of the most brilliant achievements in medical science. It is impossible to give all the details; but it may be possible to make the chief facts intelligible. Of the real nature of the virus of hydrophobia we as yet know nothing—possibly the germ belongs to the class of ultra-microscopic organisms to which reference is made later. Pasteur, however, showed that the virus resides chiefly in the brain and spinal cord of an animal dead from the disease, and further that if the nervous system is kept for a time the virus gradually becomes weaker and weaker. He accordingly devised the method of getting a series of vaccines of different strengths by preserving in a dry condition for varying periods of time, the spinal cords of rabbits dead from hydrophobia. Each cord was then disintegrated and an emulsion made which was used for injection. If a person is bitten by a rabid animal, an injection is made with part of a rabbit's cord preserved for fourteen days, on the following day with one preserved for twelve days, and so on till ultimately one kept for only one day is used. By this method immunity is gradually developed during the period of incubation, so that at the time when the disease would naturally develop, the patient is no longer susceptible. This method was first carried out in the case of the human subject in 1885, on a boy who had been badly bitten by a rabid dog. No symptoms of hydrophobia appeared, and since that time the method, in spite of certain adverse criticism, has had the confidence of all qualified to judge and has come into general use. It is now daily practised in the Pasteur Institute in Paris and in similar institutes in various parts of the world. Those interested in the subject may find in the "Annales de l'Institut Pasteur" full statistics as to the number of those treated, the proportion of the cases in which the animal was proved to be rabid, and the number in which hydrophobia developed.

Within more recent times preventive inoculation has been carried out in the case of three very important epidemic diseases, namely cholera, plague, and typhoid fever. In the method of inoculation devised by Haffkine against cholera, the steps of procedure are closely similar to those of Pasteur's method of inoculation against anthrax, a portion of a culture of weak virulence being first injected, and then after a suitable interval one of higher virulence. It was also Haffkine who introduced the method of inoculation against plague, the "vaccine" in this case being a portion of a dead culture rich in the poisonous products of the bacillus of plague. Wright and Semple's method of inoculation against typhoid, extensively carried out in the Boer war, is essentially the same in principle; here also a portion of a dead culture is injected, the method being really one of chemical vaccination. All these methods have been carried out on a large scale, and statistics have been published. Without going into details one may say, that the results are distinctly encouraging; the percentage of cases of the disease and also the percentage of mortality in these cases, being lower amongst the inoculated than amongst the uninoculated. It cannot, however, be claimed that a complete immunity is conferred by these methods, and it is also to be noted that the immunity which results lasts for only a certain period of time. Inoculation is not unattended with discomfort, and in some cases by a certain degree of illness, and manifestly it cannot be carried out generally against the various diseases. But there is no doubt that in the face of serious epidemics it constitutes an important prophylactic measure, and also that before long improved methods will yield still better results.

It may, however, be asked—what is immunity? How does the body acquire the power of destroying harmful microbes? This may be said to be the chief question before pathologists and bacteriologists in recent years, and although it cannot be fully answered, a great advance towards that goal has been made. One of the most attractive theories on this subject has been that brought forward and elaborated by Metchnikoff, and known as the theory of *phagocytosis.* I shall endeavour to state briefly the chief facts. While most of the cells of the body are fixed in position, there are also some which are often spoken of as "wandering cells," and of these, one of the most important varieties is the white corpuscle of the blood. These wandering cells have very much the characters of uni-cellular organisms such as the amoeba, and Metchnikoff looking at the matter from the point of view of the biologist, showed that such cells are present throughout the whole animal kingdom, and possess closely similar properties. Just like the amoeba they have powers of independent movement, they move towards particular objects and ingest them, and if these are digestible they produce their solution and destruction. Ingestion and digestion by such cells constitute phagocytosis, and this function is exerted by the wandering cells towards bacteria in their neighbourhood. Now Metchnikoff showed that when a person or animal is immune towards a bacterium, active phagocytosis is seen; when there is no immunity, phagocytosis is deficient or absent. And further, when immunity is artificially produced, the establishment of immunity is accompanied by an increased activity of the phagocytes. Immunity would therefore appear to depend upon what might be called an education of the phagocytes. This theory was elaborated with consummate skill, and many striking examples were brought forward in support of it. But manifestly a further explanation was demanded, viz., as to what determined the phagocytes to be active or inactive as the case might be. The answer to this would involve too complicated a discussion, but it may be stated that there are now good grounds for saying that phagocytosis is rather the evidence of the existence of immunity than the explanation of its essence. As will be pointed out later, certain substances antagonistic to the bacteria are developed during the production of immunity and these render the bacteria a prey to the phagocytes. As illustrating a means of defence, however, phagocytosis is of the highest interest and importance.

We turn now to another part of the subject, namely that of the mode of action of bacteria as producers of disease. How are their harmful effects brought about? In the case of some of the earlier diseases studied, *e.g.*, anthrax, the bacteria in the blood and tissues are so numerous, that it was thought they might act by using up the oxygen of the blood, or in some cases by blocking the capillaries of vital organs. Although such actions may sometimes be not without effect, we now know that the all-important factor is the production of chemical poisons or *toxins*. Moreover, this is not an activity peculiar to the bacteria of disease; it is merely an example of the general action of all bacteria as producers of chemical change. The study of toxins is thus one of the first importance. In its modern aspect it may be said to originate with the work of Roux and Yersin on diphtheria (1888). If a fluid culture of a bacterium is made to pass through the pores of a porcelain filter of sufficient fineness, the bacteria are retained in the pores and the filtrate is sterile. Now these observers showed that if a culture of the diphtheria bacillus was treated in this way, the filtrate possessed very poisonous properties, and on injection into an animal produced practically the same effect as the bacteria themselves. What is commonly known as "diphtheria toxin" is merely such a filtrate, and it evidently will contain the various ingredients of the culture medium as well as the toxic substances proper. Similar researches on the bacillus of tetanus soon followed, and valuable results were obtained. It is to be noted, however, as already indicated, that toxins obtained in this way are mixtures, and all attempts, even to the present time, to obtain chemically pure toxins have failed. They are probably albuminous or proteid substances, though even this is not certain; they are very unstable, being readily destroyed by heat; and we have no chemical test for any of them, the only evidence of their existence being that afforded by their physiological action. Many of them are of extraordinary potency; it has been calculated in the case of tetanus toxin, that if it is as poisonous proportionately for a man as for a mouse—as is quite likely—the dose of the tetanus toxin in the dry condition, purified as far as possible, but still probably impure, is about the three-hundredth part of a grain. The bacterial toxins to which we have been referring are set free in the culture medium and are hence usually spoken of as extra-cellular toxins, but there are also other toxins closely bound up within the bacterial protoplasm, and existence of these can only be shewn by injecting the dead bacteria themselves. Our knowledge regarding these latter—the intra-cellular toxins—is however, still less complete than in the case of the extra-cellular toxins.

Shortly after the discovery of toxins, attempts were made to confer immunity against these substances, and were soon successful. Behring and Kitasato on the one hand, and Tizzoni and Cattani on the other, independently immunised animals against tetanus toxin, and further established the remarkable fact that in the blood of immunised animals substances were present which antagonised the action of the toxin—in other words antitoxins.

This discovery is one of the highest importance both as establishing an entirely new biological fact, and also as supplying the basis for the *serum treatment* of disease. The serum of the immunised animal when mixed with the toxin and injected into another animal annuls the toxic properties; it also does so, though not so effectively, when injected some time after the toxin. The nature of antitoxic action has been the subject of much investigation, and it is now established that the antitoxin enters into loose chemical combination with the toxin, and thus prevents the latter from combining with the cells of the body and damaging them. Results similar to those obtained with tetanus toxin were obtained with the toxins of other bacteria, and the energies of investigators became directed towards employing antitoxins as therapeutic agents, the first real success being obtained by Behring in the case of diphtheria. The diphtheria antitoxin is developed on a large scale by injecting horses with increasing doses of the toxin; blood is drawn off after a suitable period of treatment, and the separated serum constitutes the "antitoxin" used for treatment, its potency having of course been previously standardised. From what has been stated it will be manifest that the antitoxin when injected into a patient suffering from diphtheria neutralises the harmful effects of the toxins in process of being manufactured by the bacilli. The antitoxin treatment of diphtheria constitutes one of the greatest triumphs of modern medicine. Brought into general application about 1894, it has since been carried out on an ever increasing scale and with ever improving results. Very extensive statistics show that the mortality has fallen to less than a half of what it formerly was. Loddo, for example, collected the statistics of 7,000 cases in hospitals in various parts of the world, and found a mortality under antitoxin treatment of 20 per cent. instead of 44 under former conditions. When tracheotomy has to be performed, the mortality has always been higher, but in this class of cases the improvement has been still more striking. And we are fully justified in saying, that, if it were not for the fact that in many cases the disease has lasted a considerable time before the diagnosis of diphtheria is made and the antitoxin treatment applied, the mortality would be still lower. An indication of this is given by the cases where diphtheria follows scarlet fever, as these cases are already under observation in a hospital and treatment can be applied at once. In the London fever hospitals the mortality from this post-scarlatinal diphtheria, as it is called, has fallen since the introduction of antitoxin treatment from 50 to between 4 and 5 per cent. In the case of lock-jaw and other diseases, antitoxin treatment has been much less successful, not because the antitoxins are less effective as such, but from certain other circumstances. In diphtheria the diagnosis can usually be made at an early stage, but in lock-jaw the first indication is generally the occurrence of spasms, and by this time the poison has so affected the nerve-cells that the mischief cannot be undone by the antitoxin. Antitoxic sera, as we have seen, act by antagonising the poisons of the bacteria, but there are also sera which produce their effects by killing the bacteria themselves —"anti-bacterial sera." These have specially been used as therapeutic agents in the treatment of certain forms of blood-poisoning ("streptococcus infection") and of plague. Here also it is easy to demonstrate experimentally the potency of such agents, but in the actual clinical application the amount of success has been comparatively small. Reasons for this might be given, but the matter is of too complicated a nature to discuss fully here. It is sufficient to state that the causes of failure are coming to be understood, and we can confidently look to improvement in this form of remedy.

Another discovery of great importance in the closing years of the century has been that of the method of *serum diagnosis.* This discovery was made first in the case of typhoid fever (1896) independently by Widal and by Grünbaum, the former, however, having priority in publication, though it was led up to by the researches of others, of whom Gruber and Durham may specially be mentioned. The method depends upon the fact that the blood serum of a patient suffering from a particular disease has a certain effect upon the bacterium causing that disease—an effect which is usually evidenced by the bacteria being clumped or agglutinated when a minute quantity of the serum is brought into contact with them. Accordingly for purposes of diagnosis all that is necessary is a small quantity of blood, which can be sent to a laboratory and there tested with the bacterium which produces the suspected disease. This method supplies by far the most reliable means of diagnosis of typhoid fever—a disease which varies very greatly in its symptomatology—and it is in daily application as part of the routine work of every public health laboratory. And, although it has been most extensively applied in the case of typhoid, it has also been carried out in the case of Malta fever, dysentery, cholera, meat-poisoning and other bacterial infections. The scientific basis of this serum test depends upon the fact that when a bacterium infects the body, there are produced by the tissues, substances which have an antagonistic effect on that particular bacterium—shewn by the agglutination—but not on other bacteria. Although usually employed for the diagnosis of disease it can also be applied to determine the nature of a bacterium. For example, a bacillus suspected to be the typhoid bacillus, can be tested with the serum of a patient known to be suffering from typhoid; if no agglutinative reaction is obtained it may be concluded that the organism is not the typhoid bacillus. It need not be pointed out that the possession of a rapid and accurate means of diagnosis is a matter of the utmost practical importance both as regards the treatment of the patient and also as regards the health of the community. The facts mentioned also demonstrate the interesting fact that during infective diseases changes are occurring in the blood and other fluids which have for their end the protection of the individual and the process of cure.

Before closing this review I wish to refer briefly to a subject which has recently been engaging the attention of investigators, namely that of the so-called *invisible micro-organisms.* The cells both of the animal and vegetable kingdoms are, for the most part, well within the range of microscopic vision, and a varying complexity of structure can usually be distinguished. With certain of the lowest forms, however, this is not the case. In the smallest bacteria, for example, some of the micrococci which measure less than the fifty-thousandth part of an inch in diameter, all that can be distinguished is a small spherical body which is coloured deeply with certain dyes—its form can be made out but no internal structure. In view of these facts it might well be asked, do such cocci really constitute the smallest living organisms? The researches of Nocard and Roux on pleuro-pneumonia published in 1898 are of great importance in this connection. These observers succeeded by certain methods in cultivating on artificial media the organism producing this disease, and obtained colonies of growth which were visible to the naked eye. When, however, they examined such colonies by the ordinary microscopic methods used for bacteria, they found that the individual organisms composing them were so minute, that even their form could not be definitely recognised. Here, accordingly, we have an organism which may be said to be on the borderland between the visible and the invisible. But there is evidence that organisms even smaller exist. In speaking of the separation of toxins from the living bacteria, we stated that the latter were retained in the pores of certain porcelain filters, and thus a fluid culture could be rendered sterile. In the case of certain recently investigated diseases, however, the filtered fluid still has the power of producing the disease, *i.e.*, still contains the living organisms although by no method can they be detected by the microscope. And further, by using porcelain of varying degrees of fineness some idea is obtained of the relative size of such organisms. Amongst the filters of commonest use, the Chamberland F has finer pores than the Berkefeld, and the Chamberland B finer pores than the Chamberland F. It has accordingly been found that some invisible organisms will pass through a Berkefeld while they are stopped by a Chamberland filter. The medium in which the organisms are, also has an influence, the presence of much albuminous matter, as in blood serum, aiding their retention in the filter. Enquiries of this kind may be said to be in their infancy, but already it has been determined that a number of organisms will pass through a Berkefeld filter though most of these are retained by a Chamberland B. Of these, the organisms of horse-sickness, of bird-plague, of yellow-fever, of cattle-plague and others might be mentioned as examples. Reed and Carroll, members of the American Army Commission on yellow-fever, found that the blood serum of a patient affected with this disease still possessed its infective properties after it had been passed through a Berkefeld filter, although no organisms could be detected in the serum. And in the case of other infective diseases, where attempts to obtain the causal organisms have not yet succeeded, it is quite possible that these also belong to this ultra-microscopic class.

At the outset of the lecture it was stated that at the beginning of the nineteenth century knowledge both of the constitution of the human body and of the micro-organisms which infect it, was of a very rudimentary kind. We have endeavoured to show how medical science during the century is rich in advances in both of these departments. The conception of the body as in a sense a colony of cells, and of the chief causes of disease as various unicellular organisms which invade the tissues, marks a great advance. The conflict between the patient and something called

Hence, for the discussion of the future of a country, the first thing to be done is to consider which of these external influences may be the principal factor to modify the evolution of the present nation in that country, and to what degree the other external influences are negligible, without an appreciable error being made. Next we ought to examine whether the present inhabitants are capable of adapting themselves to that environment.

If they are incapable by the law of Natural Selection, they will cease to progress, or decline, and some other nation or nations more fitted to the environment will displace them and flourish in the country. If they are capable, their future will be promising.

In discussing the future of Japan, therefore, first of all the principal external influences affecting the growth and development of the present Japanese must be found, and secondly whether they are capable of adapting themselves to an environment of this sort is to be considered.

Japan consists of a chain of islands numbering with its islets as many as 4,870 (including Formosa, Pescadores, and the adjacent islets ceded to Japan from China). They cover an area of about 161,000 square miles, containing at present about 47,000,000 of people, i.e., 202 to a square mile.

The rapidity with which the population of Japan is increasing is shown by the following table :—

Year.	Population.	Increase.	Increase per 100 of people.
December 31, 1894,	41,813,215,	——	—
" 1895,	42,270,620,	457,405,	1·09
" 1896,	42,708,264,	537,644,	1·04
" 1897,	43,228,863,	520,599,	1·22
" 1898,	43,763,855,	534,992,	1·24
" 1899,	44,260,642,	496,787,	1·14
" 1900,	44,805,937,	545,295,	1·23

Thus the population of Japan is increasing by about half-a-million every year.

Now the inhabitants of Japan are rather unevenly distributed over the Empire. Hokkaido and Formosa are most thinly populated, in spite of their being very promising islands. So that the emigration from the densely populated places to the thinly populated places is continuously going on, and before long the two islands of Hokkaido and Formosa will be sufficiently populous. Then the emigration to Korea, China, and other countries will become a pressing necessity for the self-existence of Japan. The emigration to foreign countries is already carried on on a large scale.

A rapid increase of the population of a country is a sign of her prosperity if all the people can bring their energy into action; but it is a cause of the decay, if they cannot. Now Japan is in a critical position. If a proper place can be got for utilising the energy of her increasing people and augmenting their welfare, she will be able to establish herself as a great nation in the East; but if it cannot be got, her Empire will become a place of poverty and starvation. Hence the encouragement of emigration, the protection of rights and interests of the emigrants, are highly important for Japan.

Hokkaido, Formosa, Korea and other foreign countries to which Japanese are emigrating are all separated from the mainland of Japan. It is therefore essential for her to be predominant at sea in the East, so that her subjects may be well protected in these separated places.

The failure of Japan in maritime affairs would mean failure in emigration, which would lead to her destruction. Even at present her independence and existence are greatly dependant upon the navy. For instance, in the Russo-Japanese War which is now going on, the successive severe blows at Chemulpo and Port Arthur gave Japan complete command of the sea, so that she can carry on the war further for the protection of her rights and interests. But if, on the contrary, Russia having got command of the sea, cut off communications between the islands of the Japanese Empire, and blockaded the ports, one can easily imagine, what great difficulties the nation of Japan must experience. Neither her half a million of brave soldiers, nor the indomitable spirit of patriotism would save the country.

Although emigration and agriculture are well encouraged in Japan, if the country make great commercial and industrial developments in future, it is very propable that she will become like the present Great Britain where the people mostly live on foods from foreign lands. Then power on the sea will become vital for Japan.

Thus the fortune of Japan is completely dependant upon maritime affairs. If she fail in them her fate will be sealed, no matter how successful she may be in other things. If she succeeds in them and utilises the energy of her increasing people to the full extent, her prosperity will be ensured.

But the essential thing for maritime success in any country is that her geographical situation and condition are favourable. Hence the chief factor on which the fortune of Japan depends, is the geographical situation and the condition of her Empire, i.e., this may be considered as the principal factor which shapes the future career of the Japanese nation.

First it will be shown that the Empire is geographically well fitted to develop as a sea-power in the East, and secondly we will discuss whether the Japanese are capable of adapting themselves to this favourable environment for development.

THE GEOGRAPHICAL SITUATION OF THE JAPANESE EMPIRE.

Japan has three gigantic neighbours. In the East she has the United States, and in the West and North, she has the two great Empires of China and Russia.

The completion of the Panama Canal on the Nicaragua will revolutionise the Pacific Ocean. It will afford a new route from Europe and the Eastern coast of America to Asia. Again the Canadian Pacific Railway which was completed in 1887 provides a transcontinental route from Halifax on the Atlantic to Vancouver on the Pacific. From Vancouver steamers extend the journey to Japan and China. The shortest route from Great Britain to Asia is by this way, except the railway route through Siberia. Its wonderful success has already had much influence upon the condition of the Pacific.

Hence very soon there must be a great change in China. Her invaluable natural resources will no longer be left untouched. Coal, which is very plentiful and widely diffused in China, will be fully worked, and rich stores of iron, copper, lead, zinc, etc., unearthed. The Chinese rich red lands and fertile yellow lands capable of producing unlimited quantities of tea, silk, grain, etc., will be far better cultivated by the application of science. Many steamers and railways will be made to bring the productive centres into better connection with the ports, and the characteristic low wages of Chinese labour will also play an important part in developing industry. The influx of Western Civilisation will revolutionise China in every way.

It is rather strange that, despite the keenness and the enterprising spirit of Europeans and Americans, such a promising country as China should be left in its present undeveloped state. Their struggle for industrial and commercial success, is so sharp, almost fierce, in their own countries, where there is hardly enough room to satisfy their ambitions, while on the other hand the vast field of Asia, with inexhaustible natural resources, and rich land capable of producing an inestimable amount of wealth, is still in a state of stagnation.

This is simply owing to the lack of good communications between the East and the West till recently. The marvellous success of the Canadian Pacific Railway, and the completion of the Panama Canal on the Nicaragua, will not allow this awkward state of things to exist any longer. China will become a field of great speculations and enterprises, and the natives will be obliged to throw off their old customs and hereditary anti-foreign feeling.

Besides these new routes, there is another organ which will hasten the evolution of Asia, that is the Siberian Railway. This railway connects St. Petersburg on the Baltic and Vladivostok on the Sea of Japan. Its length being 4,300 miles, it is the longest railway in the world. It has an important branch from Harbin to Port-Arthur. The branch passes through Mukden, Niuchwang, and Dalni.

The railway was unfortunately used by Russia for military purposes to achieve her long desired aggression on China and Korea, and obliged Japan to take arms. As a result of the war, however, Russia will be made to use it solely for the purposes of commerce, which is the unanimous wish of Japan, Great Britain, and the United States.

Then there must be remarkable changes in Siberia and Manchuria, Omsk, Tomsk, Irktsk, Harbin, Mukden, Niuchwang, Dalni, Port Arthur, Vladivostok, etc., which, now military and naval bases of Russia, will become important industrial or commercial centres. The condition of Korea also will be much improved by the completion of the Seul-Fusan Railway, and the Seul-Wiju Railway.

The Russo-Japan War is no doubt a great blow to the present commerce and industry of Asia. But the war is preferable to the keeping of what may be termed "armed peace" for a long time, and ultimately bursting into hostilities. Russia will be taught something good by the present war, and her deep-sighted statesmen will be able to decide whether it is wise or not to apply her aggressive policy towards China and Korea against the will of Japan. It is very probable that the present war will hasten the evolution of Asia, as the French Revolution brought a new era to European civilisation.

Now, considering the geographical situation of Japan, the evolution of the East, which will necessarily come in this generation, will put her on the high road of commerce between the Eastern and the Western worlds. Her situation in Asia is very like that of Great Britain in Europe.

History tells us that those places which lie on the high road of commerce, and which offer to commerce good harbours and profitable interchange of commodities, are most favourable for development as maritime towns. The development of Venice, Genoa, Constantinople, Amsterdam, Liverpool, London, Glasgow, and the like, is entirely due to these causes.

In the near future, Japan as a whole will lie on the high road of commerce between the East and the West. She will be placed practically in the centre of three large markets—Europe, Asia, and America. As regards geographical situation, therefore, she is almost ideally fitted for development as a sea-power.

THE GEOGRAPHICAL CONDITION OF THE JAPANESE EMPIRE.

Next let us discuss the geographical condition of the Japanese Empire.

It is well known that the maritime development of a country greatly depends upon the number of indentations of the coast line; or the length of the coast line, compared with the area of the country, is an important factor of development.

The area of the Japanese Empire is about 161,000 square miles, and the length of the coast line is about 18,140 miles, i.e., one mile of coast line per 8·8 square miles of land. The numerous indentations of the coast line supply it with many good ports suitable for commerce and for naval stations.

Hokkaido, one of the four largest islands forming Japan proper is not well indented compared with the others. The most important port in this island is Hakodate. The port lies on the Strait of Tsugaru, which separates Hokkaido from Hondo (the main island of Japan). It is a fortified place with inhabitants numbering about 80,000, and a large foreign trade is carried on. It is the port for the very rich coal-mining district in the Southern portion of Hokkaido. The second important ports in Hokkaido are Muroran at the entrance of Volcano Bay, Otaru on the Ishigan Bay, and Kushiro facing the Pacific.

On the gulf opposite to Hakodate there lie Aomori and Ominato. The former is a commercial port, and the latter is a naval station. The important ports on the Eastern coast of Hondo, are Ishinomaki, Yokosuka, Yokohama, Shimizu, Taketoyo, Atsuta, Yokkaichi, Tsu, Kure, Shimonoseki, etc.

Ishinomaki lies midway between Hakodate and Yokohama, and iron as well as other minerals are chiefly exported. Yokosuka and Yokohama are on the Tokyo Bay. The former is a most important Japanese naval station. It has dockyards capable of repairing battleships over a tonnage of 15,000. Shipbuilding is also carried on there. Yokohama with about 200,000 inhabitants is a well known port for the foreign trade of Japan. It is at a distance of 18 miles from Tokyo, the capital of Japan. The entrance to Tokyo Bay is well fortified to protect Yokosuka, Yokohama and Tokyo.

Shimizu is a small but growing port on the Suruga Bay. Taketoyo, Atsuta and Yokkaichi are small ports on the Ise Bay. The entrance to the Bay is strategically very important, but it is not yet fortified. This may be considered as a weak point of Japan. Kobe and Kure lie on the beautiful inland sea formed by Hondo, Shikoku and Kiushu. Kobe, with a population of over 210,000, is about twenty miles from Osaka, the largest city in Japan, next to Tokyo. It is a most important port for the foreign trade of Japan. Kure is one of Japan's best naval stations. There are docks for repairing the largest battleships afloat and yards for building ships. Kure is well fortified and the numerous islets at the entrance make the port extremely difficult of attack. Shimonoseki lies on the narrow channel between Hondo and Kiushu, and is the terminus of the Sanyo Railway. The entrance to the strait is strongly fortified.

The most important ports on the Western coast of Hondo are Maizuru and Nügata. The former is a very important naval station; the latter is a commercial port, first opened to foreign trade along with Yokohama, Kobe, Nagasaki and Hakodate. It is not in a flourishing state compared with the other four. The ports next in importance on the Western coast are Hamada, Sakai, Miyatsu, Tsuruga, Fushiki, Sakata, Tsuchisaki and Nanao. Nanao is a naval port, while all others are commercial ports.

The ports of the Western coast of Japan at present are not so flourishing as the ports of the Eastern coast. But they will become very important if the Siberian Railway turns out to be a great trade route.

The island of Shikoku lacks large ports, but Maruyama and Tadotsu on the inland sea are somewhat noteworthy ports. The Western coast of Kiushu is characterised by having numerous indentations and many islands in its vicinity. Nagasaki, Saseho, Kuchimatsu, and Misumi lie on this coast. Nagasaki is a port where foreign trade is largely carried on. Saseho is a famous naval station. With regard to the present Russo-Japanese War, it is a very favourable station for the Japanese navy. Moji on the Shimonoseki Strait, facing the town of Shimonoseki, is a port where the coal trade is most extensively carried on.

The coast of Formosa is not well indented, and is often stormy. Kirin, Tansui on the northern coast, and Takao, Amping on the south-western coast are the only ports in the island. In the Pescadores which is adjacent to Formosa, there is a naval station of considerable importance. In Tsushima, which lies at the middle of the Korean Strait, there is also a naval port.

These are very brief notices of the present important ports of Japan. There are many other ports of minor importance. The harbour of Osaka, a busy commercial and manufacturing city, is not adapted at present for ships of large tonnage. But the work of improving the harbour is now going on, the completion of which will make Osaka a splendid port. There is also a plan of improving the harbour of Tokyo, which is very shallow and at present not well protected from storms.

Japan, not only has many promising ports, but can supply commerce with profitable interchange of commodities, such as rice, barley, soja-beans, red-beans, Italian millet, ruck-wheat, rape-seed, potatoes, sweet potatoes, cotton seeds, hemp, leaf-tobacco, leaf-indigo, and tea, which are her chief agricultural products. Mulbery trees are also extensively cultivated for the silk industry. Lumbering is also carried on a good deal.

Japan is, moreover, rich in natural resources, gold, copper, iron, antimony, manganese, sulphur, petroleum, and coal, being its chief mineral wealth. Marine products are also plenty. Fish is indeed the chief animal food of the Japanese.

As regards the geographical condition, Japan is also suited to succeed on sea. Nature affords the islands of Japan all necessaries for development as a sea power in the East. Hence let us next consider whether the Japanese are able to avail themselves of this beneficial assistance of Nature.

THE JAPANESE AND THE SEA.

Since very ancient days the Japanese have had a great interest upon the sea. Even their legends are rich in stories concerning the sea. After the time of legends passed, their first historical maritime success was the subjugation of Korea in the beginning of 200 A.D. by the Japanese Empress Jingo, who personally commanded her fleet and troops.

As a result of this heroic event a busy intercourse commenced between Japan and Korea, and Chinese civilisation as well as Buddhism were introduced into Japan by Koreans. Soon after this communication between Japan and China began and rapidly developed; many Japanese went to China to learn, and many Chinese came to Japan to teach. Numerous Chinese Classics and Kyo (canonical books of Buddhism translated into Chinese), together with various Chinese utensils, tools, and weapons were imported into Japan. In those days the Chinese were far more advanced than the Japanese, both mentally and materially, so that the latter welcomed the civilisation of the former with the same enthusiasm as now they are embracing Western Civilisation.

Much intercourse with foreign lands necessarily advanced the arts of shipbuilding and navigation in Japan. At the same time the enterprise and energy of the Japanese took another and less lawful direction. Piracy arose in Japanese waters and soon grew formidable. Bands of fierce pirates carried on their nefarious trade in combination, and their undaunted courage and subtle manœuvres made it almost impossible for the government to subdue them.

In 1200 A.D., however, Yoritomo Minamota, a famous Japanese military ruler, temporarily succeeded in quieting them. But after his death they soon regained their original activity in working mischief, and their number and ferocity increased with time.

These pirates were often employed by the chiefs of clans for sea-fights, as they proved to be splendid fighters. Afterwards they were even employed by the government as sailors under the name of Kaizokushu, which literally means "a body of pirates." In spite of this infamous name they did good service to the government.

At the end of 1200 A.D., the Manchurians invaded Japan with 140,000 men on 3,500 ships, but met with such fierce opposition from those pirate sailors of Japan that they could not land. Then opportunely a violent storm arose and the whole Manchurian fleet was annihilated.

Following upon this naval victory the Japanese pirates becoming more ambitious, went far off to Korea, China, and even to Anam, Siam, Burma, Philippines, etc., to extend their spheres of business, and they ravaged beyond description. The exploits of the daring pirates became the topic of daily conversation among the unfortunate people of the plundered countries.

It is worthy of note that during the unsuccessful invasion of Korea at the end of 1500 A.D, by Hideyoshi, a hero of Japan, the Japanese sailors, chiefly consisting of pirates and those descended from them, were remarkable for their great courage.

The growth of pirates in Japan is no doubt a barbarous sign, but it shows that, unlike the other Asiatic peoples, the Japanese were very energetic and enterprising in sea affairs even in olden days.

In the middle of the 16th century, Spain and Portugal were active in the East, and Japan was induced to open trade with them. In those days, quite different from the other Asiatic races, the Japanese were very friendly to foreigners, and consequently foreign intercourse considerably developed. Many ships were built, and people and Government worked hand to hand in the encouragement of foreign trade.

Beneficial intercourse with European countries, especially Spain, Portugal and Holland continued for nearly a century. Then on account of the interference of Europeans in Japanese politics, a rigorous order for the purpose of checking foreign intercourse was issued by the Government of Tokugawa Shogun. We will not go into details of the order and its issue. Briefly, by this order all countries except Holland, China, and Korea were prohibited from intercourse with Japan, and no Japanese was allowed to go abroad. Any one who infringed this rule was subject to capital punishment, and his or her relatives were also prosecuted.

Although at first many pirates, in violation of the order, were committing ravages abroad, especially near Formosa, even they were ultimately obliged to relinquish their lawless occupation.

Progress in Japan was thus arrested for the space of about two-and-a-half centuries.

But even this period of stagnation could not extinguish the enterprising spirit of the Japanese in maritime matters. Since 1853, when the Americans demanded a treaty of commerce with them, they have again become active at sea. The voyage of the "Kanrinmaru," a small steamer, to the United States, in 1860, by order of the Tokugawa Government, furnishes a good example of the recovery of ancient activity. For the voyage was wholly conducted by Japanese, who had seen steamers for the first time in 1853, and not until two years later did they begin to learn how to manage them.

In the revolution of 1868 the feudal system was abolished and the Emperor restored. Towards the end of the revolution there took place a great sea-fight near Hakodate between the navy of the Emperor and that of the followers of Shogun. This was the first naval engagement conducted by the Japanese in Western style, and they fought with the fiercest determination.

After the restoration of the Emperor, Japan made rapid progress in industry, commerce, education, etc. Her navy and army were organised according to European methods, and grew strong enough to beat China in the Chino-Japanese War (1894-1895). As a result of that war Japan became known all over the world, and new treaties were signed between her and the Western powers. Thereafter she made progress in every direction with increasing rapidity.

The recent progress of Japan cannot be considered as of a spasmodic and convulsive nature. The intrepid and pushing spirit of the Japanese is well shown by the bold enterprise of their pirate ancestors, who made great havoc, not only among other Asiatic people, but also among Spanish and Portuguese traders who came to Asia. Without regarding piracy itself as other than barbarous and inhuman, the Japanese may be excused for feeling some pride at having inherited the fearless and energetic nature which distinguishes them, as it did their piratical forefathers, from the other races of Asia.

It was simply by the strict conservative policy of the government of Tokugawa Shogun that the progress of Japan was temporarily stopped. There is now no such policy, the nation is free to develop; and, judging from what the Japanese did in the past, it is highly probable that they will develop as a maritime nation.

CONCLUSION.

Thus it has been shown that the nation of Japan has a most favourable environment for development, and also the capacity of adapting themselves to it. We must therefore conclude that she has a very promising future. It is the aim and duty of the Japanese to avail themselves of the geographical advantages of their country; to become the Britain of the East, and for the welfare of mankind to introduce into Asia the civilisation of the West. Although this end is still far off, Japan is making steady progress towards it.

Age Incidence in Zymotic Diseases. (A contribution from the Sanitary and Social Economy Section). By JOHN BROWNLEE, M.A., M.D., (Glasg.), D.P.H. (Camb.), Physician Superintendent, City of Glasgow Fever Hospital, Belvidere.

[Read before the Society, 24th February, 1904.]

THE subject of this paper is a consideration of the meaning of the statistics of infectious diseases, as they occur at different ages, in the light of the mathematical developments of the theory of probability which have been divised in recent years, especially by Professor Karl Pearson. The needs of astronomers and surveyors long ago made the adoption of some means of reconciling discordant observations a practical necessity. It early came to be generally recognised that if an observation were made a certain number of times with equal care, and with equally perfect instruments, the most probable value of the quantity observed is the arithmetical mean or average of the values given by the observations. From this, what is commonly called the normal probability curve, was deduced as a necessary consequence. The normal probability curve, which is figured in diagram I., is the geometrical expression of the frequency with which any error of definite magnitude may be expected to occur in a number of observations. It is symmetrical about the middle line, which indicates that positive and negative errors are equally likely to occur. The ordinate or vertical distance of any point on this curve from the base line decreases in value as the error increases in magnitude, thus large errors occur with great infrequency, while small ones are much more numerous. The example which is most commonly chosen to illustrate the application of this law to practical problems is taken from rifle shooting. Given a good shot, using a rifle without bias, the atmosphere being clear and steady, out of a given number of shots bull's eyes will constitute the most numerous group ; inners will follow, then outers, while misses will be the rarest of all. As many shots will fall to the right of the bull's eye as fall to the left, and as many above as below. This kind of grouping extends very widely throughout nature. If in considering, for example, the stature of children at a definite age, the children are graded so that they fall into groups in accordance with their height, it will be found that there is a height which is more frequent than any other, and with each inch of difference above or below this, the numbers in the groups tend to grow smaller and smaller, while giants and dwarfs are exceedingly rare. When, however, this method is applied extensively it is quickly seen that this symmetry does not obtain to any very large extent in nature's groups, the numbers tending to be distributed more to one side of the line of maximum frequency than to the other. This gives the curves a character, which is called "Skewness" by Professor Karl Pearson. As an example of what is meant, the illustration of the rifleman can again be employed: he was referred to as shooting under ideal conditions, but let there be in addition a variable wind blowing across the range, and it is evident that the number of shots striking the one half of the target will somewhat exceed those striking the other. All the distributions which are considered in this paper, except one, belong to this class of "Skew" curves, few instances of an infectious disease grouping itself with regard to age incidence so as to approximate to the normal curve existing. For each disease there is a definite period of life at which the maximum susceptibility occurs, and above and below this the number of cases becomes gradually smaller and smaller though the fall in numbers may occur much more quickly on one side than on the other. Thus in scarlet fever the maximum frequency of attack is between four and six years, while under one year and over forty, few cases occur.

The manner in which the mathematical theory of probability is applied to such cases as this is briefly as follows. The form of the curves which represent distributions in the production of which chance is the main factor are first thoroughly investigated. For this Professor Pearson is practically the sole authority. The classes of statistics which it is desired to examine are then tested as to how far they conform with the distributions admitted by the theory. Discrepancy between the facts and the theory, if it exists, can be observed. Of the causes of this, inadequacy in the number of observations is one. It may also be due, and in the class of fever statistics is commonly due, to the presence of some factor in addition to the most important, namely the age susceptibility, acting specially at some age period. An obvious instance is given by the age distribution of persons suffering from measles: the susceptibility to this disease decreases with each year of life from four years upwards, but on the curve of age distribution a marked secondary rise takes place between the ages of seventeen to thirty,[1] which, when examined into, is found due to immigration to Glasgow of persons from country districts from which measles has long been absent, who consequently form a new population of susceptible persons at an age period at which among natives of Glasgow few such are to be found. It would seem that one of the chief advantages offered by the application of the method in our case is to determine at what ages such causes are specially to be looked for. The method by which the appropriate probability curve can be found from the observations given in the statistics cannot be explained here. It depends in principle upon obtaining the curve belonging to the group of probability curves which has the same moments about a vertical line through its centre of inertia as has the curve given by observations. The first moment about a vertical line is that obtained by multiplying each vertical strip by its distance from the fixed line as in the process of finding the centre of the centre of gravity, the second by the square of that distance as in finding the "moment of inertia," the third by the cube of the distance, and the higher moments in the same way.

In general in infectious disease the origin of the curve must be placed at birth. With this assumption the number of moments required is reduced from four to three. It is true that in a few diseases abortion takes place, and some of these cases of premature birth may be due to the fœtus having acquired the disease from which the mother is suffering. This especially applies to smallpox and to typhus fever, but with regard to all other infectious diseases such is either of great rarity or impossible. The point of origin of the curves in general must thus be taken at the date of birth. Two classes of curves satisfy an asymmetrical distribution which begins at zero, rises to a maximum and then declines. In one of these the upper limit is definite and in the other indefinite. With most infectious diseases the susceptibility becomes so small at high ages as to be almost nil, and although it is more logical to assume a definite limit to life yet the simplification in calculation involved in leaving the upper limit undefined is so great, and the difference of the number of cases at high ages given by the two assumptions is so very minute, that I have not hesitated to chiefly use the latter. It is found by trial that the age distribution follows this theoretical grouping very closely when diseases are considered which chiefly affect adults; thus, enteric fever, typhus fever, and smallpox in vaccinated persons, show a very marked correspondence between the theoretical and the actual distribution of cases. Prof. Pearson has fully discussed the case of enteric fever. He takes the statistics of 8,689 cases of this fever treated by the Metropolitan Asylums Board Hospitals. The fit of the theoretical curves is here exceedingly close, but those given by considering the higher moments of the curves demand placing the origin of the curve at respectively 1.3 and 2.8 years before birth. When the origin is assumed to be at birth the fit is not quite so close. This, however, is what is a priori to be expected. Susceptibility to a fever cannot be expected to vary only according to only one law from birth to old age, even when the disease is essentially one affecting adults. To pass from enteric fever to typhus the statistics of the male patients suffering from this fever, and treated in Belvidere Fever Hospital, have been chosen for consideration. The diagram[1] shows the kind of correspondence which the theoretical curve bears to the actual statistics. It will be seen that the theoretical curve has a course such that the curve of actual observations zigzags backwards and forwards across it. One interesting variation noticed here, and also when the statistics of London are similarly examined, is that at the age of from forty to fifty-five years, the actual numbers are in excess of the theoretical ones. These are the years at which habitual drunkenness has fixed its mark on its devotees, and it would seem to be indicated that such persons not only offer themselves more easy victims to this disease when attacked, but in addition are more susceptible to the infection. The same condition has likewise been noted clinically as predisposing to pneumonia. A similar diagram is given of the deaths among the same series of cases. Here on account of smaller numbers the actual curve is much more irregular than that noted among the cases, which number about eight times those of the deaths. The fit of the theoretical curve is thus not so close. When, however, the two are combined so as to form a theoretical mortality curve it will be seen that, the same zig-zagging of the actual, through the theoretical again takes place, and at only two points is there a serious discrepancy. One of these exceptions is in the first five-yearly period (0·5 years), where it is known that the mortality among children under three years is specially high. This comes under a group of special infantile susceptibility which will be discussed later. The other exception is in the age group fifty-five to sixty-five years, where the number of cases and deaths is small and the liability to error consequently great. It is thus probable that the theoretical value is in this case much more accurate than the observed, a conclusion borne out when comparison is made with the tables of age mortality in other Hospitals.

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[1] See Appendix.

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[1] Diagram II.

It will lead to a more easy development of the question if the age incidence in the case of whooping cough[1] be considered next. This disease is almost absolutely one of childhood. It is true that in the Hospital statistics, a number of females occur above the age of twenty, but these are largely nurses or nursing mothers who are necessarily brought into such special contact with the disease as to constitute a completely new method of infection. The statistics of the male patients are therefore chosen as more likely to represent the actual grouping of the disease. It will be seen at once by reference to the appendix that a theoretical curve beginning at birth bears little or no resemblance to the actual distribution of the cases. If by the method of successive approximation an attempt is made to split up the actual curve into groups of cases a result such as is seen in diagram III. is easily arrived at. The method is as follows: at each age period where the theoretical number given by the first found curve is in defect of the actual, the former is chosen and a theoretical curve found for this new grouping. This process is repeated until two succeeding theoretical curves do not greatly differ, and it is found then that the remaining cases throw themselves into two groups, one beginning at birth and practically ending at three years, another beginning about four years and ending about nine years. When these curves are arranged and added, the result forms a close approximation to the form of the whooping cough curve. It is not pretended that this splitting up of the curve into these three factors is more than a rough approximation or the only method by which the obviously compound form of the actual curve may be represented. A similar result, however, is obtained when the problem is attacked by the method of least squares and a probability curve fitted to the figures representing the number of cases in each of the first twelve months of life, the residue being considered as a compound curve. This analysis appears to bear the following interpretation. There is a period during infancy of special susceptibility to whooping cough. The second group represents the normal susceptibility to the disease during the age of childhood. This has its maximum between the ages of three and four years. The third group which increases the number of cases at higher ages begins about four years of age, and has its maximum at six. There seems little doubt that this represents the amount of disease which is spread by infection in schools. An exactly similar splitting up of the compound curve which represents the age incidence in measles can be made. The special susceptibility under one year of age, however, is not so great, while the part played by schools is greater. This special infantile susceptibility may also be noted to a small extent in the case of scarlet fever.[1]

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[1] See Diagram III.

The age distribution of the cases of smallpox both in unvaccinated and vaccinated persons can now be analysed. Among the former there is a very great infantile susceptibility. A second period of susceptibility occurs as in measles between the ages of three and four years. When a probability curve is fitted so as to begin at birth, and apply chiefly to the years above six, it will be found to have a correspondence with the observations of a closeness shown by no other fever except enteric. This curve of which the figures are given in the appendix was found by trial. There is no evidence at all of schools spreading the disease, a fact which can readily be understood when it is considered that the great majority of scholars are protected against the disease by vaccination, and that the character of the disease in unvaccinated persons is of a severity such as is in general will prevent their attendance at school. When the case of vaccinated persons is considered in the same manner, they are also seen to form a homogeneous group. The chief variation is at early ages, and it is to be noted in support of the truth of the statistics, that the curve based on them considered as a whole gives a very close fit. In its points of difference it demands considerably fewer cases at the ages at from five to fifteen years than are given in the actual numbers, showing that the tendency to classify cases occurring at these early ages as unvaccinated, which the anti-vaccinators constantly claim is done, can hardly have arisen in the minds of those responsible for the collection of the statistics.

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[1] See Appendix.

The statistics of scarlet fever remain to be considered. Here again as with measles and whooping cough no theoretical curve with its origin at the point of birth can be obtained which bears any particular resemblance to the actual distribution of the cases. If the higher moments are considered so that no assumption is made as to the point of origin, the resulting theoretical curve thus obtained much less represents the facts. The age distribution of scarlet fever must thus be considered due to a variety of contributory causes, acting in different degrees at different ages, as have been already seen to be the case with whooping cough and measles. Spread by schools may from the very first be put out of count. Definite school infections are very rare in Glasgow, and the influence of schools in spreading the disease, if any, must be looked for in the steady supply of small numbers of cases due to the presence of the poison either in small amount or in attenuated form. The holidays in Glasgow usually comprise most of the last fortnight in June and extend through July. The incubation period of scarlet fever is rarely more than 8 days, so that the age distribution of cases of this disease in July must represent that existing when dissemination of the poison by schools does not exist. The schools resume work after the holidays early in August, and the usual rise of scarlet fever begins in the middle of that month. At this period a large number of children are sent to school for the first time, and these must include many susceptible to the disease. If then scarlet fever were spread by schools to any extent, the percentage of cases occurring at the ages of five to twelve ought to considerably exceed that occurring at these ages during the month of July alone. As a matter of fact the percentages occurring at each age period are practically identical.[1]

At higher ages (from fifteen years and upwards) another factor evidently comes into play, about half the cases occurring in persons of country extraction. Even, however, if the number of these is subtracted from the total numbers and a theoretical curve calculated for the residue no better fit is obtained. All the curves with their origin at birth, which I have calculated by trials such as these demand a very much larger number of cases between the ages of one and four, and a much smaller number at ages over fifteen than are given by the actual figures. The best fit on the whole is that obtained by considering the figures from four to twelve years of age, as representing the normal distribution of the disease in childhood—which can be safely done so far, inasmuch as schools play little part in its dissemination—and calculating the corresponding theoretical curve by the method of least squares. The excess at the ages 0-5 of the theoretical values above the actual is not now so marked, though it still obtains, but the theoretical numbers are only a fraction of the actual ones at all ages above twelve. This difficulty may be explained partly by immigration to Glasgow of susceptible persons as already mentioned, but partly also by the fact that infection of parents or nurses is not unusual, and a new factor influencing the spread of the disease is thus introduced. I have not succeeded any further than this in fitting to the scarlet fever statistics a compound curve, which approaches the actual facts with any closeness.

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[1] See Appendix.

In conclusion, it may be stated that there is a very close correspondence of the theoretical and actual curves when those diseases affecting adults chiefly are considered. The application of the method, however, to diseases of children where special infantile susceptibility spread by schools, etc., are definite factors is a matter of great difficulty.

A

AGE DISTRIBUTION OF TH
DISEASES OF CHILD
BELVIDERE, 1886-

Measles.	
Age-Periods.	Cases.
Months.	
0— 1	3
1— 2	7
2— 3	10
3— 4	19
4— 5	36
5— 6	42
6— 7	108
7— 8	113
8— 9	145
9—10	129
10—11	122
11—12	86
Years.	
1— 2	1,227
2— 3	1,545
3— 4	1,718
4— 5	1,600
5— 6	1,503
6— 7	1,235
7— 8	796
8— 9	398
9—10	214
10—11	110
11—12	60
12—13	47
13—14	28
14—15	23
15—16	29
16—17	33
17—18	34
18—19	63
19—20	91
20—21	113
21—22	117
22—23	111
23—24	88
24—25	79
25—26	78
26—27	52
27—30	77
30—35	52
35—40	12
40—50	7
50—60	2
All Ages,	12,362

Whooping-Coug	
Age-Periods.	Cases
0— 1	1
1— 2	1
2— 3	3
3— 4	5
4— 5	4
5— 6	6
6— 7	8
7— 8	8
8— 9	9
9—10	6
10—11	7
11—12	4
1— 2	61
2— 3	74
3— 4	77
4— 5	69
5— 6	58
6— 7	42
7— 8	22
8— 9	11
9—10	5
10—15	3
15—20	
20—25	
25—35	
35—45	...
45—56	
Total,	4,96

Whooping Coug		
Males. Age Period	Cas	
0— 1	323	1
1— 2	304	4
2— 3	345	4
3— 4	330	3
4— 5	299	2
5— 6	266	2
6— 7	201	1
7— 8	103	
8— 9	51	
9—10	25	
10—15	12	
15—20	1	

NOTES ON APPENDIX.

IN the appendix, tables are given of the age distribution of measles, scarlet fever, and whooping-cough in such detail as may allow the observation of the various periods of special susceptibility. In the case of whooping-cough a special table is given showing the number of cases at each age period among males, and for comparison the numbers given by the corresponding theoretical curve whose first two moments are identical, and whose origin is at birth. This curve is referred to in the text.

A table is also given showing the age distribution of cases of scarlet fever during the holiday months and the months immediately succeeding the holidays for comparison.

Tables showing the actual and theoretical distribution among vaccinated and unvaccinated cases are added. The vaccinated persons are divided into four classes—those who have sparse, abundant, or confluent eruptions, and those in whom the disease was hæmorrhagic.

The equations of these curves are as follows :—

Vaccinated cases

Sparse eruption, $y = 95{\cdot}9\left(1 + \frac{x}{9{\cdot}983}\right)^{5{\cdot}8056} e^{-x \times {\cdot}58155}$

unit of $x = 2{\cdot}5$ years.

Abundant eruption, $y = 64{\cdot}77\left(1 + \frac{x}{11{\cdot}869}\right)^{8{\cdot}6634} e^{-x \times {\cdot}72992}$

unit of $x = 2{\cdot}5$ years.

Confluent eruption, $y = 26{\cdot}013\, e^{-\frac{x^2}{(4{\cdot}096)^2}}$ (the normal curve)

unit of $x = 2{\cdot}5$ years.

Hæmorrhagic Cases, $y = 4{\cdot}5516\left(1 + \frac{x}{14{\cdot}2103}\right) e^{-x \times {\cdot}65494}$

unit of $x = 2{\cdot}5$ years.

Unvaccinated Cases, $y = 107{\cdot}24\left(1 + \frac{x}{3{\cdot}205}\right) e^{-x \times {\cdot}11013}$

unit of $x = 1$ year.

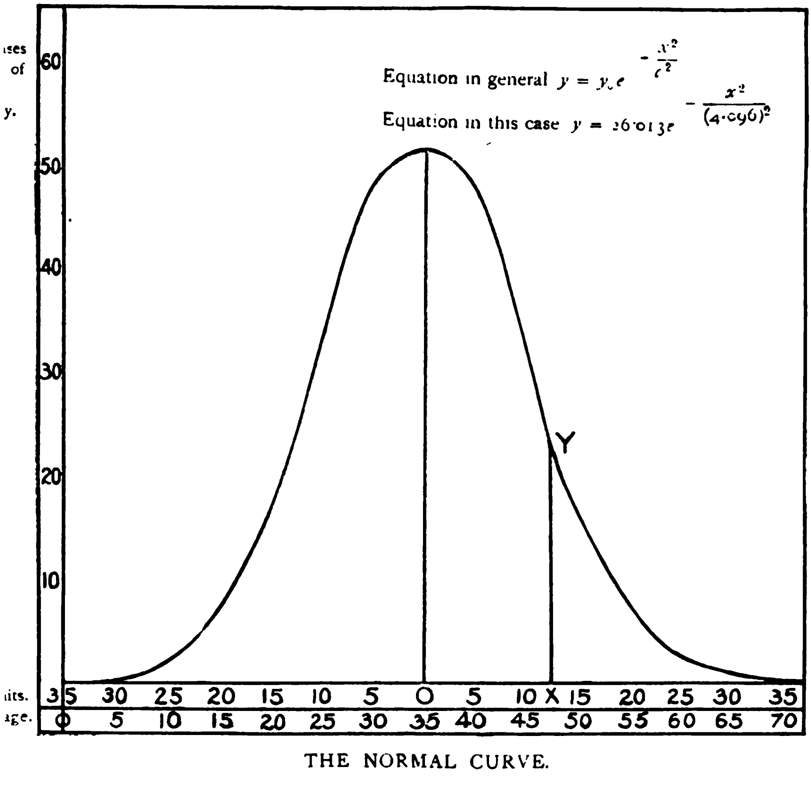
The point of origin of all these curves is the age period of maximum frequency. It will be noticed how among the vaccinated class the distance of this from the zero ordinate, which represents birth, increases with the severity of the attack. Thus among cases with a sparse eruption the age of maximum frequency is twenty-five years (2·5 × 9·98), among those with an abundant eruption 29·6 years, among those with a confluent eruption 35·2 years, and with a hæmorrhagic one 35·5 years. It is noticeable that those cases with a confluent eruption are distributed so as to nearly coincide with that given by the normal curve, and thus obey the law of error. The point of maximum frequency is 35.2 years, and it is evident from the curve that the protection afforded above this period by advancing age exactly corresponds to the loss by lapse of time of the protection afforded by vaccination between the period at which that operation was performed and the age of maximum frequency.

In contra-distinction to this it is noticeable that the first few years of life constitute the period of maximum attack rate among the unvaccinated.

NOTES ON THE DIAGRAMS.

Diagram I.—The normal curve of error.—The abscissa O X measured from the middle point of the base line represents the size of the error. The ordinate X Y measures the frequency of that error so that it is easily seen that negative errors are equally common with positive, and that the larger O X is, the smaller is X Y. This curve very appropriately represents the distribution of confluent cases of smallpox, and is drawn to the scale as in the figures given for such cases in the appendix.

Diagram III.—Composite curve of whooping-cough. It is to be noted in this diagram that the second and third curves which go to make up the composite curve, which consists of heavy dots, are drawn to a slightly larger scale than is correct in order to avoid unnecessary confusion in the diagram. The fit of the composite curve is therefore considerably closer than is represented.



THE NORMAL CURVE.

DIAGRAM I.

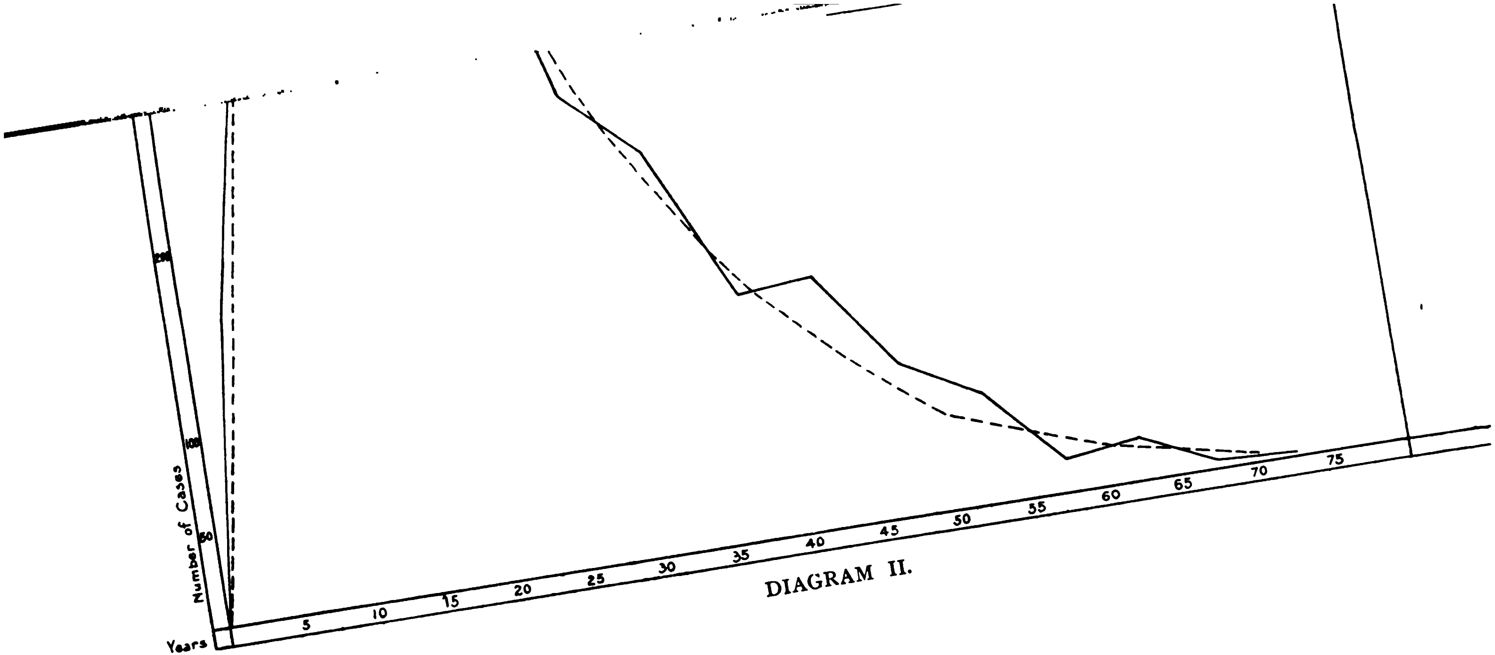

200
100
50
Number of Cases
Years
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75

DIAGRAM II.

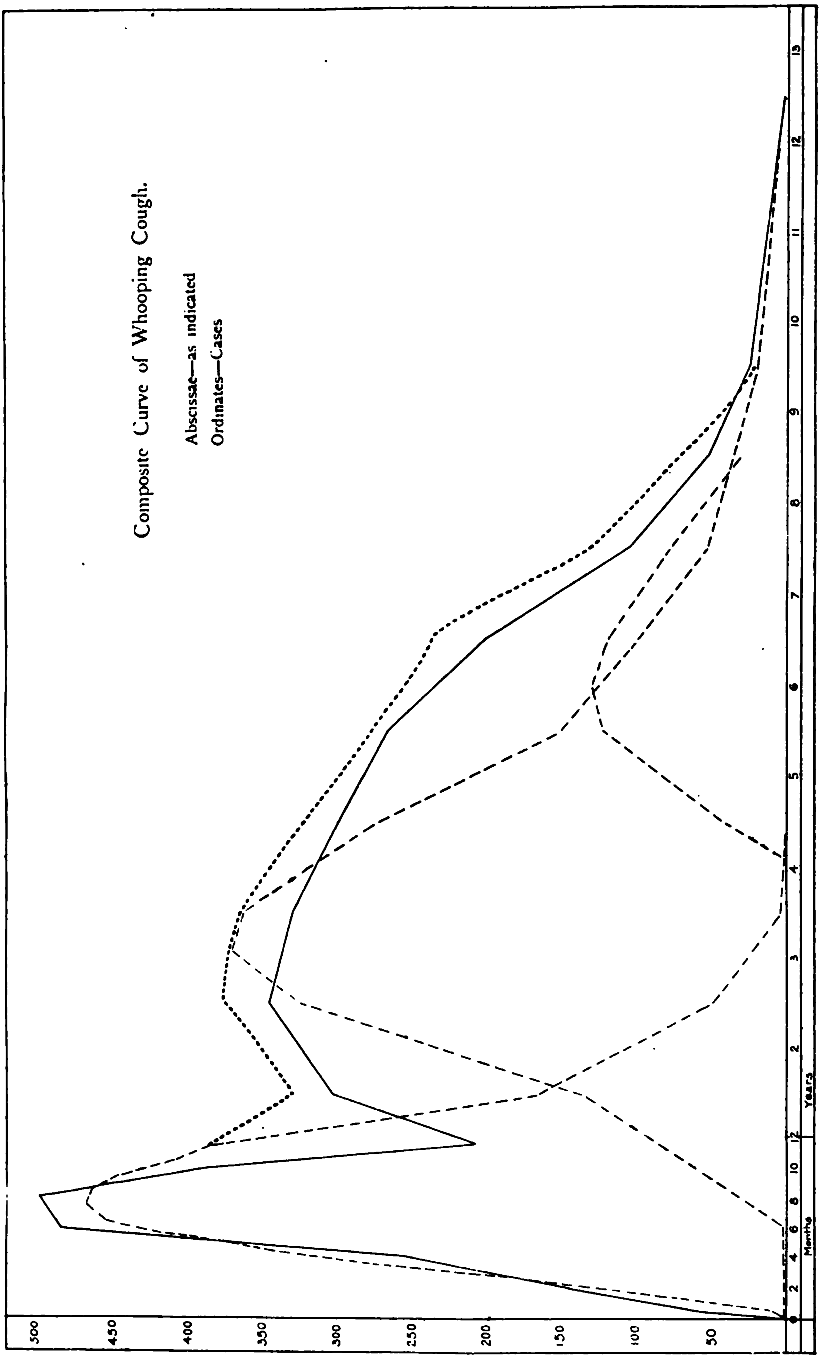

Composite Curve of Whooping Cough.
Abscissae—as indicated
Ordinates—Cases
500
450
400
350
300
250
200
150
100
50
0
2
4
6
8
10
12
Months
Years
2
3
4
5
6
7
8
9
10
11
12
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DIAGRAM III.

RULES GOVERNING THE COMPETITION FOR THE GRAHAM MEDAL.

1. The competition for the Graham Medal shall be under the authority and control of the Council of the Royal Philosophical Society of Glasgow, whose decision on all points connected therewith shall be final.

2. Each candidate shall forward to the Secretary of the Royal Philosophical Society of Glasgow, 207 Bath Street, Glasgow, on or before 14th March of the year in which the competition is held, a paper giving an account of an unpublished original research conducted by himself in any branch of chemical science.

3. The medal shall be awarded to the candidate whose research, in the opinion of the Council, or of the person or persons whom they may appoint to adjudicate in the matter, is of the highest merit, and most likely to aid in the advancement of chemical science.

4. The successful candidate shall read the paper, on account of which the medal is awarded, to the Royal Philosophical Society of Glasgow. The paper shall thereafter be published in the *Proceedings* of the Society, and its publication elsewhere shall not take place without the permission of the Council.

5. No award shall be made if, in the opinion of the Council, no candidate has contributed a paper of sufficient merit.

MINUTES OF SESSION.

1903-1904.

4th November, 1903.

The First Ordinary Meeting, for the Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Natural Philosophy Class Room, Glasgow University, on the evening of Wednesday, 4th November, 1903, at eight o'clock. The President, Professor Archibald Barr, D.Sc., occupied the Chair.

1. The Hon. Secretary intimated that no Minute would be read, as that for the previous Meeting was published in the last issue of the *Proceedings*, and had been read and approved at the close of the Meeting itself.

2. Mr John Alison, Mr J. Roberton Christie, the Rev. James Bell Grant, and Mr C. W. Bream Pearce, were admitted to Membership of the Society.

3. Mr Frank W. Young and Mr James D. Borthwick were appointed to audit the Hon. Treasurer's accounts.

4. The President called upon Professor A. Gray, LL.D., F.R.S., to give the opening lecture of the Session and the first of the special centenary series on the Advancement of the Sciences during the last hundred years.

Professor Gray delivered a lecture on "The Progress of Electricity in the Nineteenth Century, and the Electro-Magnetic Theory of Light." Numerous illustrative experiments were made in the course of the lecture, and many photographs of pioneers in electrical science shown on the screen.

5. A vote of thanks was accorded to Professor Gray on the motion of Principal Story. Appreciative remarks were also made by Professor M'Kendrick and Professor Blyth.

6. The President announced that the following gentlemen had been elected Members of the Society:—

1. Mr CHARLES E. BECKETT, M.A., LL.B., Writer, 163 St Vincent Street.
2. Mr JOSEPH DAWSON CAMPBELL, Writer, 142 West George Street.
3. Mr WILLIAM M. DOUGLAS, 155 North Street.
4. Professor ROBERT FULLARTON, M.A., M.B., F.F.P.S.G., 276 Bath Street.
5. Mr ALBERT A. GRAY, M.D., 14 Newton Terrace, Glasgow, W.
6. Mr WILLIAM F. M'AUSLAND, Merchant, 51 Buchanan Street.
7. Mr R. C. MACKAY, Writer, 82 West Regent Street.
8. Mr FRANCIS M'KEAN, Commission Agent, 235 Bath Street.
9. Mr DAVID BAIRD SMITH, LL.B., Writer, 205 St Vincent Street.
10. Mr JOHN ROSS YOUNG, Writer, 65 Bath Street.

REPORT OF COUNCIL FOR SESSION 1902-1903.

I. *Meetings.*—Session 1902-1903 was formally opened on 5th November by the President, Professor Barr, with his presidential address on, "Some Points in the Early History of the Society," a subject peculiarly appropriate as the opening of the Centenary celebration. Twelve ordinary and two extraordinary meetings of the Society were held during the Session, at which fourteen papers were read. The business at the two extraordinary meetings was concerned with the registration of the Society's title "Royal."

II. *The Sections.*—Still greater activity in the prosecution of the work of the Sections in their special departments falls to be reported. All the Sections contributed papers to meetings of the Society, and four issued full syllabuses of papers for general and sectional meetings early in the Session. Several of the papers read at sectional meetings are printed in Vol. XXXIV. of the *Proceedings.*

III. *The Proceedings.*—Volume XXXIV. of the *Proceedings* was issued to members towards the end of September. Fifteen papers have been inserted which occupy 322 pages, or a few pages over the space taken up by the twenty-one papers in the issue for last Session.

IV.—*Graham Medal.*—There was no competition for the Graham Medal last Session.

V.—*The Centenary Celebrations.*—The great event of the Session and one of the most important and brilliant in the history of the Society, was the celebration of the hundredth anniversary of its foundation. The celebration may be said to have begun on 5th November with the President's address, and following this, as mentioned in the last report of Council, a Conversazione took place in the Kelvingrove Art Gallery and Museum, on the 12th November, 1902, and a banquet in the Windsor Hotel on the 13th.

At the meeting of Council of date the 18th January, 1902, it had been unanimously resolved that the Centenary of the Society's foundation, which would fall on 9th November following, should be celebrated, and that in a manner befitting the position which the Society held in the West of Scotland. A committee, with the President as Convener was appointed to consider arrangements for the celebration, and report. The committee held many meetings during the Spring and Summer, and at the beginning of Autumn submitted their report to a meeting of Council. The scheme recommended was adopted by the meeting and the same committee appointed to carry out the arrangements proposed.

The main features of the scheme were that the celebrations should consist of two parts: First that an Exhibition and Conversazione, lasting from 8 to 10.30 p.m., be held on the 12th November, and a Banquet on the 13th, and that tickets for the Banquet be sold to members of the Society only. Second, that the leading Scientific and Philosophical Societies and Educational Bodies in Great Britain and Ireland, and the Universities in Scotland, be invited to take part in the celebrations by representation, and that delegates should receive invitations to both Conversazione and Banquet.

The list of the delegates who were present will be found in the *Proceedings*, Vol. XXXIV., pp. 330, 331. Mr William Ewing, and a small sub-committee undertook to make arrangements for entertaining delegates from a distance; and a number of gentlemen kindly offered hospitality for these during their stay.

It was originally intended to place on view, in the hall chosen for the Conversazione, as many models, specimens, documents, pieces of scientific apparatus, and such other objects of interest as could be secured for the purpose. Professor Magnus Macleau and a sub-committee were deputed to collect exhibits. But the great labour entailed in procuring a large number of exhibits, and arranging them to the best advantage, was very materially lessened, and the difficulty of securing a suitable hall entirely overcome by the kindness of the Lord Provost and the Corporation of the City, who generously placed their new Museum and Art Galleries, Kelvingrove at the services of the Council for the Conversazione. Thus it happened, that, except the ceremony of opening the Kelvingrove Art Gallery and Museum, which took place a few days previously, the Society's Conversazione was the first public function held within the building. Professor Maclean was then able to report that, as the treasures of the Museum, and the splendid works of art with which the galleries abounded, would be placed on view during the Conversazione for the benefit of members and guests, his committee considered three additional exhibits sufficient. One would be provided by Professor Andrew Gray, and would consist of physical apparatus used by some famous scientists in making their classical experiments; a second would consist of selected specimens from the Marine Biological Station at Millport, provided by Mr John A. Todd, Secretary of the Association; and the third, objects pertaining to the Society itself, and would include the Society's great chair, the first minute book of the Society, a scrap-book containing many documents of historical interest, the original die with which the seal of the Society was impressed, and the first Diploma issued by the Society just one hundred years before. Information regarding some of these was given by the President in his opening address, referred to above.

The Conversazione.—It was estimated that the number of ladies and gentlemen present at the Conversazione, including members and guests, was between

3,000 and 4,000. These were received, on entering, by the President, Prof. Barr, assisted by Mrs. Barr and the Vice-Presidents. When all were assembled the President, from the organ-loft, formally welcomed the guests of the Society; and the Hon. the Lord Provost (Mr John Ure Primrose) in turn extended a welcome in the name of the Corporation to the members of the Royal Philosophical Society of Glasgow and their friends. The occasion was the first on which Mr Primrose had the opportunity of taking part in a public function as Lord Provost. Professor E. A. Schäfer replied on behalf of the delegates, and presented the following address from the Royal Society of London:—

> "The ROYAL SOCIETY OF LONDON for the Advancement of Natural Knowledge sends fraternal greetings to the ROYAL PHILOSOPHICAL SOCIETY OF GLASGOW on the completion of a century of corporate activity.
>
> The ROYAL SOCIETY earnestly desires continued success and prosperity to an institution whose objects are the same as its own, and looks forward with pleasure to future co-operation on behalf of the advancement of knowledge.
>
> Bearing in mind the great names of members in the past, and also at the present time, that have constituted a link between the two Societies, the valuable influence they have exerted and the great work they have achieved, the ROYAL SOCIETY desires to associate itself in a very special manner with this Centenary celebration."

The address bears the seal of the Royal Society, is dated 30th October, 1902, and signed "William Huggins, President R.S."

Professor Magnus Maclean proposed a vote of thanks to the Lord Provost and the Corporation for their great kindness to the Society in granting the use of the Museum and Art Gallery for the Conversazione. The proposal was responded to with the utmost heartiness.

Selections of organ and orchestral music were given throughout the evening, and refreshments provided.

The Banquet.—On the following evening, the 13th November, the celebration of the Centenary concluded with a banquet held in the large dining hall of the Windsor Hotel, St Vincent Street. Over 230 gentlemen sat down to table, of whom about 60 were guests. The chair was occupied by the President of the Society, Professor Archibald Barr, and Professors John Glaister and Magnus Maclean acted as croupiers. Nine parallel tables were arranged across the hall, and touching one end of each was the upper table which ran along the length of the hall. The upper table and two central tables were reserved for the President and past-Presidents, the representatives of Societies, and other guests. On the right and left of the President sat the Lord Provost and Lord Kelvin, respectively.

TOAST LIST.

1. The King, - - - - - - - The Chairman,
(Prof. Archibald Barr, D.Sc., M.Inst., C.E.)
2. The Queen, the Prince and Princess of Wales,
and the other Member of the Royal Family, - The Chairman.

3. The Imperial Forces, - - The Very Rev. Principal Story, D.D.
Replies, - - Col. Forbes M'Bean, C.B., Gordon Highlanders.
Col. Smith Park.

4. The Royal Philosophical Society of Glasgow, - - - - Prof. E. A. Schäfer, LL.D., F.R.S.

5. Our Guests, - The Right Hon. Lord Kelvin, O.M., G.C.V.O., F.R.S.
Replies, - - - - Mr James Burgess, C.I.E., F.R.S.E.
Prof. Arthur Schuster, Ph.D., F.R.S.
Prof. John M. Thomson, F.R.S., F.I.C.

6. The City of Glasgow, - - - - Prof. John Glaister, M.D.
Reply, - - The Hon. The Lord Provost (Mr John Ure Primrose).

7. The Universities and other Educational Institutions, - - - The Very Rev. Donald Macleod, D.D.
Replies, - - - - - - - Principal Yule Mackay, M.D.
Mr R. M. Mitchell.
Mr W. R. Copland, M.Inst. C.E.

8. The Chairman, - - - - Prof. Francis Elgar, LL.D., F.R.S.

The financial account of the Centenary Celebration will appear in the statement of the Hon. Treasurer; but it may be mentioned here that it was not the intention of the Council that members who purchased tickets for the banquet should thereby contribute largely, or at all, to the expense incurred by entertaining the very large proportion of guests who were present; and as no part of this expense could be drawn from the funds of the Society, it was decided to meet the deficit by voluntary subscriptions obtained privately from a few members, and that any surplusage from this fund should be transferred to the funds of the Society. The work of raising this fund was remitted to Mr Ewing, assisted by a small committee.

At the meeting of Council of date 19th November, 1902, it was agreed that the thanks of the President and Council should be accorded and transmitted to the following for valuable services rendered in connection with the celebration :—

The Lord Provost and the Corporation of the City; The Marine Biological Association of the West of Scotland; Mr J. V. Stevenson, Chief Constable; Mr James Paton, Curator of the Kelvingrove Art Gallery and Museum; Mr A. G. Lindsay, Superintendent of Police, Western District; Mr James Whitton, Parks' Superintendent; Mr John Young, Manager of the Tramways; and Mr J. Roberton Christie of Edinburgh, who kindly lent for exhibition the first Diploma issued by the Society.

The same meeting resolved "That this Council felicitate Professor Barr on the aptness, eloquence, and signal ability with which, first in his paper read before the Society at last meeting, afterwards at the conversazione, and particularly at the banquet, he represented the Society on its Centenary; and express the gratification universally felt over his presidential appearances throughout the functions."

The thanks of the meeting were also given and recorded to Dr. Freeland Fergus, Hon. Secretary, and to Professor Peter Bennett, Acting Secretary, for their hearty co-operation in all the work of the Council connected with the Centenary celebrations.

At the meeting on 3rd December the Society, to mark its appreciation of the cordiality with which the various learned societies and corporations throughout the land responded to the invitation to assist at the celebration of its centenary, made the following additions to the Roll of Honorary and Corresponding Members:—

Honorary Member.

Professor **Edward Albert Schäfer**, LL.D., F.R.S., M.R.C.S., University of Edinburgh.

Corresponding Members.

John George Bartholomew, F.R.S.E., F.R.G.S., Edinburgh.
James Burgess, C.I.E., LL.D., F.R.S.E., Hon. A.R.I.B.A., F.R.G.S., Edinburgh.
Francis Elgar, LL.D., F.R.S., F.R.S E., London.
Frederick Emley, Newcastle-upon-Tyne.
Professor **Cargill G. Knott**, D.Sc., F.R.S.E., Edinburgh.
Principal **John Yule Mackay**, M.D., LL.D., Dundee.
Professor **John Millar Thomson**, LL.D., F.R.S., F.I.C., F.C.S.
Professor **Robert Wallace**, F.R.S.E., F.L.S., F.C.S., Edinburgh.

VI. *Membership*—At the beginning of the Session there were 975 Ordinary Members on the roll. During the Session 66 Members were elected, and 2 reinstated from the Suspense List, making 1,043. Of these 29 have resigned, 15 have died, 1 has been placed on the Suspense List, and four struck off for non-payment, so that at the beginning of Session 1903-1904 there were 994 Ordinary Members on the Society's list. The following are the deaths, viz.—Messrs. Jas Craig Arnot, Wm Borland, John Brown, Wm Foulis, C.E., James M. Gale, C.E., John Gray, George Munsie, F. N. Sloane, C.A., Hugh Steven, Jas Stevenson, LL.D., James Macintyre Thomson, David Tullis, Wm Turner, John Watson, Hugh Wallace, nine of whom were Life Members. Of the new Members admitted during the Session, 15 qualified themselves as Life Members, and 6 old Members likewise qualified. There are now 273 Members of that class out of 322 who have so enrolled themselves. The roll now includes 16 Honorary Members, 19 Corresponding Members, and 994 Ordinary Members (Annual and Life), or a total of 1,029.

VII. *Finance.*—The Treasurer's statement for 1903-1904 opens with a balance of £12 7s. 9d. in his hands, an investment in railway stock of £47 9s. (the remainder at cost, of a larger investment partly sold), and £150 in deposit. The accounts close with £10 16s. 1d. in the Treasurer's hands with the same investment, and £450 deposited with the Corporation of Glasgow. It is believed that, as usual at the close of the financial year, the Society has practically no outstanding liability.

Separate statements are given by the Treasurer, as formerly, showing the position of the two funds which the Society holds in trust, viz. :—"The Graham Medal and Lecture Fund" and "The Glasgow Science Lecture Fund," the balances of revenue being £71 0s. 1d. and £44 2s. 7d. respectively.

FREELAND FERGUS, *Hon. Secretary.*
PETER BENNETT, *Acting Secretary.*

REPORT OF THE LIBRARY COMMITTEE.

The Library Committee have to report that during last Session, exclusive of periodicals, 99 volumes and 8 parts of works were added to the Library by purchase, and 41 volumes, 16 parts, and 7 pamphlets were presented.

The periodicals received at the Library numbered 110, of which 69 were bought, and 41 received in exchange or presented.

The *Proceedings* of the Society were sent to 183 Societies and Public Departments, and 167 volumes, and 163 parts were received in exchange.

Altogether during the year there were added to the Library 201 volumes by purchase, 157 by exchange, and 41 were presented, making an estimated total of 14,952 volumes, exclusive of pamphlets, and abridgments of specifications of Patents.

During the Session 921 volumes were issued by the Librarian to 679 members.

Since last report 249 volumes have been bound.

Members are reminded that recommendations of books for addition to the Library may be made in the book kept in the Library for the purpose.

The new catalogue has been for some months in the printer's hands, and the Committee hope to be able to send it out to Members at an early date.

JOHN ROBERTSON, HON. LIBRARIAN,
Convener.

18th November, 1903.

The Annual Business Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 18th November, at eight o'clock. The President, Professor Archibald Barr, occupied the Chair.

1. The Minute of previous Meeting, of date 4th November, 1903, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. On the motion of the Chairman, Dr George Neilson was elected Vice-President in succession to Professor Glaister.

4. On the motion of the Chairman, Mr John Robertson, Mr John Mann, and Dr Freeland Fergus were re-elected Honorary Librarian, Honorary Treasurer, and Honorary Secretary, respectively, and a vote of thanks for their past services accorded to them.

5. On the motion of the Chairman, Mr John Mann, Jun., Professor R. S. Thomson, Mr A. E. Scougal, and the Right Hon. Lord Inverclyde were elected Members of Council.

6. Office-bearers of the different sections (see pp. 337, 338) were proposed as below and elected :—

(*a*) For the Geographical and Ethnological Section—Mr William Ewing proposed those on list, p. 338.

(*b*) For the Sanitary and Social Economy Section—Mr William Buchanan proposed those on list, p. 337.

(*c*) For the Mathematical and Physical Section—Mr H. Stanley Allen proposed those on list, p. 338.

(*d*) For the Economic Science Section—Mr H. A. Mavor proposed those on list, p 338.

(*e*) For the Historical and Philological Section—Mr. John Clark proposed those on list, p. 338.

7. The Annual Report by the Council (printed in the Second Billet), was held as read, and, with a slight alteration suggested by Mr M'Kellar, was adopted on the motion of the Chairman.

8. The Hon. Treasurer submitted abstracts of accounts for the past year, signed by the Auditors, Mr Frank W. Young and Mr R. C. Mackay. Dr Fergus stated that one of the Auditors appointed at last Meeting having been unable, through pressure of business, to undertake the work, the Council had appointed Mr R. C. Mackay to act instead, subject to the approval of the Meeting. Approval was signified, and the Hon. Treasurer's statements adopted on the motion of the Chairman.

The Auditors received the thanks of the Meeting for their services on the motion of the Hon. Treasurer.

9. The Hon. Librarian submitted the Annual Report of the Library Committee, and moved its adoption. The report was adopted, and a vote of thanks passed to donors of books.

The business of the Ordinary Meeting was then proceeded with.

10. Mr H. Stanley Allen, M.A., B.Sc., read a paper on "Experiments in Radio-Activity," being a communication from the Mathematical and Physical Section. The paper was illustrated with lantern views and experiments. Mr Allen showed specimens of the chloride of the new element Radium, and gave demonstrations of its chief properties.

Dr. **ABSTRACT OF HONORARY TREASURER'S**

AND COMPARISON WITH

			1902-1903.	1901-1902.
			£ s. d.	£ s. d.
To BALANCES from last year—				
Investment, Caledonian Railway £110, 3 per cent.				
Preferred, Converted, - - - - -		£47 9 0		
Deposit—Corporation of Glasgow, - -		150 0 0		
Clydesdale Bank on Deposit, - - -		200 0 0		
In Treasurer's hands, - - - - -		12 7 9	409 16 9	*213 10 11½*
,, SUBSCRIPTIONS to 31st October, 1903—				
64 Entry-moneys of 1902-1903,				
at 21s., - - - -	£67 4 0			
Annual Dues at 21s				
Arrears, - - - - -	1 1 0			
For 1902-1903, 669 Ordinary				
Members, - - - -	702 9 0			
Do., 49 New Members, - -	51 9 0			
		822 3 0		
Life Subscriptions at £10 10s.—				
6 Old Members, - - -	£63 0 0			
15 New Members, - - -	157 10 0			
		220 10 0	1042 13 0	*900 18 0*
,, SUBSCRIPTIONS OF ASSOCIATES OF SECTIONS—				
ARCHITECTURAL,				
79 Associates, at 5s., - - - - - - -			19 15 0	*17 15 0*
MATHEMATICAL AND PHYSICAL,				
5 Associates, at 5s , - - - - - - -			1 5 0	*0 5 0*
ECONOMIC SCIENCE,				
33 Associates, at 5s., - - - - - - -			8 5 0	*6 0 0*
GEOGRAPHICAL AND ETHNOLOGICAL,				
5 Associates, at 5s., - - - - - - -			1 5 0	*1 10 0*
HISTORICAL AND PHILOLOGICAL,				
11 Associates, at 5s., - - - - - - -			2 15 0	*2 5 0*
,, DIVIDENDS, ETC.—				
Dividends on Caledonian Railway Stock,		£3 2 4		
Interest on Deposit with Corporation, -		3 14 5		
Bank Interest, - - - -		8 11 3		
Proceedings, etc., sold, - - -		2 5 0		
			17 13 0	*11 16 4*
,, Balance due to Treasurer, - - - - - -			10 16 1	*0 0 0*
			£1514 3 10	*1154 0 3½*

Memo.—The Society's Investments are—

(1) Bath Street Joint Buildings, as in last Account, - - - -	£3,933 7 4½
(2) Caledonian Railway Stock, as above (present value, £83 17s. 6d.),	47 9 0
(3) Deposit with Corporation of Glasgow, - - - - - -	450 0 0
	£4,430 16 4½

ACCOUNT—SESSION 1902-1903. *Cr.*

SESSION 1901-1902.

			1902-1903.			*1901-1902.*		
			£	S.	D.	£	S.	D.
By MANAGEMENT EXPENSES—								
Remuneration to Acting Secretary,		£100 0 0						
Allowance for Treasurer's Clerks,		15 0 0						
Commission to Collectors,		6 16 0						
Telephone Rent,		5 5 0						
Stationery,		4 17 1						
Fire Insurance on Library,		6 10 0						
Postages, etc.—Per Secretaries, £11 14s. 10d.; per Treasurer, £8 0s. 2½d.,		19 15 0½						
			158	3	1½	*189*	*4*	*5*
,, EXPENSES OF ROOMS, one half of £520 9s. 4d.; less half of £95 3s. 0d. received for Lettings,			216	10	8	*111*	*9*	*3½*
,, LIBRARY—								
New Books and Periodicals, British and Foreign,		£162 7 5						
Bookbinding,		45 12 1						
			207	19	6	*199*	*6*	*8*
,, PRINTING, ETC.—								
Printing *Proceedings*, Circulars, etc.,		£214 10 11½						
Postage and delivery of Circulars,		45 19 6½						
			260	10	6	*219*	*6*	*4*
,, CENTENARY CELEBRATIONS—								
Expenses of Reception,		£210 11 10						
Expenses of Banquet,	£157 9 7½							
Subs. towards same,	214 9 6							
		56 19 10½						
			153	11	11½	*0*	*0*	*0*
,, SUBSCRIPTIONS TO SOCIETIES—								
Ray Society, 1903,		£1 1 0						
Palæontographical Society, 1903,		1 1 0						
Royal Institution of Public Health,		1 1 0						
			3	3	0	*2*	*2*	*0*
,, EXPENSES OF SECTIONS PER SECRETARIES—								
Architectural,			11	18	8	*13*	*1*	*8*
Mathematical and Physical,			0	3	11	*0*	*5*	*0*
Economic Science,			2	18	11	*4*	*17*	*6*
Geographical and Ethnological,			0	5	0	*0*	*3*	*0*
Historical and Philological,			0	16	1	*1*	*5*	*8*
Sanitary and Social Economy,			0	13	6	*3*	*2*	*0*
,, INVESTMENTS—								
Caledonian Railway £110, 3 per cent Preferred, Converted (Balance),		£47 9 0						
Corporation of Glasgow, on Deposit,		450 0 0						
			497	9	0	*397*	*9*	*0*
,, BALANCE in Treasurer's hands,			0	0	0	*12*	*7*	*9*
			£1514	3	10	*1154*	*0*	*3½*

GLASGOW, 13th November, 1903.—We, the Auditors appointed by the Society to examine the Treasurer's Accounts for the year 1902-1903, have examined the same, of which the above is an Abstract, and have found them correct, the Balance due to Treasurer being Ten Pounds, Sixteen Shillings and One Penny Sterling.

(Signed) FRANK W. YOUNG.
JNO. MANN, C.A., *Honorary Treasurer.* (,,) R. C. MACKAY.

GRAHAM MEDAL AND LECTURE FUND.

ABSTRACT OF TREASURER'S ACCOUNT, SESSION 1902-1903.

Dr.

CAPITAL AT 1st NOVEMBER, 1902—		
Glasgow and South-Western Railway Co. 4 Per Cent. Preference Stock in name of the Philosophical Society, in Trust,	£250 0 0	
Value of Die at H.M. Mint,	18 18 0	
		£268 18 0
Cash in Bank,		60 4 2
REVENUE—		
Dividend, March, 1903, less Tax	£4 13 9	
,, Sept., ,, ,,	4 14 10	
Interest from Bank,	1 7 4	
		10 15 11
		£339 18 1

Cr.

CAPITAL AT 31st OCTOBER, 1903—		
Investment, *per contra*, (present value, £296 5s.),	£250 0 0	
Die,	18 18 0	
		£268 18 0
BALANCE, BEING REVENUE—		
In Bank, on Deposit Receipts,		71 0 1
		£339 18 1

GLASGOW, 13th November, 1903.—Examined and found correct.

(Signed) FRANK W. YOUNG.
R. C. MACKAY.

JNO. MANN, C.A., *Honorary Treasurer.*

THE SCIENCE LECTURES ASSOCIATION FUND.

ABSTRACT OF TREASURER'S ACCOUNT—SESSION 1902-1903.

Dr.

CAPITAL AT 1st NOVEMBER, 1902—		
£200 Caledonian Railway Company 4 Per Cent. Preference Stock, No. 1, in name of the Philosophical Society, in Trust, cost,	£244 4 8	
On Deposit Receipt,	8 5 4	
		£252 10 0
Cash in Bank (Revenue),		35 12 4
REVENUE—		
Dividend, April 1903, less Tax,	£3 15 0	
,, Oct., ,, ,,	3 15 10	
Interest from Bank,	0 19 5	
		8 10 3
		£296 12 7

Cr.

CAPITAL AT 31st OCTOBER, 1903—		
Investment, *per contra*, (present value, £237),	£244 4 8	
In Bank, on Deposit Receipt,	8 5 4	
		£252 10 0
BALANCE, BEING REVENUE—		
In Bank, on Deposit Receipt,		44 2 7
		£296 12 7

GLASGOW, 13th November, 1903.—Examined and found correct.

(Signed) FRANK W. YOUNG.
R. C. MACKAY.

JNO. MANN, C.A., *Honorary Treasurer.*

Some discussion on Radio-Activity followed the reading of the paper, in which part was taken by Mr P. Falconer, Professor Gray, Dr Sloan, Professor Blyth, the Chairman, and Mr Allen.

A vote of thanks was passed to Mr Allen on the motion of the Chairman.

11. The Hon. Secretary announced that the following two gentlemen had been elected Members of the Society.

1. Mr Robert A. Burr, M.A., 26 Barnwell Terrace, Govan.
2. Mr John Chisholm, Manager, District Water Trust, Airdrie.

2nd December, 1903.

The Third Ordinary Meeting, for Session 2903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 2nd December, at eight o'clock. The President, Professor Archibald Barr, occupied the Chair, and was supported by Mr John A. Todd, President of the Economic Section.

1. The Minute of previous Meeting, of date 18th November, 1903, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. A discussion on "The Fiscal Policy," arranged by the Economic Science Section, was opened by Professor William Smart, Phil D., LL.D. Mr Alexander Cross, M.P., Mr Barclay, Mr Wingate, Mr Carlile, Mr J. Munn Ross, Mr A. A. Mitchell, Mr Lester, Mr Thomas Wilson, Mr Gow, Mr Joces, Mr Dobbie, Mr Wm. Ewing, Mr Aiton, Mr P. Falconer, and Professor Barr, took part in the discussion.

Professor Smart replied, and was accorded the thanks of the Meeting on the motion of the Chairman, for his introduction to the discussion.

4. The Hon. Secretary announced that the following gentlemen had been duly elected Members of the Society:—

1. Mr JOHN CARSWELL, F.F.P.S.G., L.R.C.P.Ed., 5 Royal Crescent, W., Glasgow.
2. Mr WILLIAM MARTIN, Tanner, Hide and Leather Factor, 63 Brunswick Street.
3. Mr ROBERT MILLER, General Manager, Caledonian Railway, 2 Rosslyn Terrace, Kelvinside.
4. Mr ANDREW ACWORTH MITCHELL, Writer, 163 St Vincent Street; House, 7 Huntly Gardens.
5. Mr ALEXANDER MALCOLM WILLIAMS, M.A., Principal, Church of Scotland Training College.

16*th December*, 1903.

The Fourth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 16th December, at eight o'clock. The President, Professor Archibald Barr, occupied the Chair.

1. The Minute of previous Meeting, of date 2nd December, 1903, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Professor Magnus Maclean, M.A., D.Sc., F.R.S.E., read a paper entitled, "The Historical Development of the Different Systems of Education in the Highlands," being a communication from the Historical and Philological Section.

After the reading of the paper, Mr Scougal, Dr Colville, and Principal Williams spoke at some length on the same subject.

A vote of thanks was accorded to Professor Maclean, on the motion of the Chairman.

4. The Chairman intimated that the following gentlemen had been duly elected Members of the Society:—

1. Mr Michael Johnston, Merchant, 19 Waterloo Street.
2. Mr F. J. Shand, 4 Bowmont Gardens, Kelvinside.
3. Mr Hugh Walker, M.A., M.B., C.M., 52 Kilmarnock Road, Shawlands.

6th January, 1904.

A Special Meeting of the Royal Philosophical Society of Glasgow was held in the Physiology Class-room, Glasgow University, on the evening of Wednesday, 6th January, 1903, at eight o'clock. The President, Professor Archibald Barr, occupied the chair.

Professor John G. M'Kendrick, M.D., LL.D., F.R.S., delivered a lecture on "Voice Tones," with particular reference to the results and methods of an experimental research.

During the course of the lecture, speech and vocal music were reproduced by means of an arc-light; and an apparatus was shown in action which automatically graphed on a uniformly moving plane the variations of intensity characteristic of the different vowel sounds.

Many other experiments and lantern illustrations were shown.

A hearty vote of thanks was accorded to Professor M'Kendrick, on the motion of Professor Gray, seconded by Dr Finlayson.

13th January, 1904.

The Fifth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 13th January, 1904, at eight o'clock. The President, Professor Archibald Barr, occupied the Chair.

1. The Minutes of Meetings, of dates 16th December, 1903, and 6th January, 1904, having been printed in the Billet calling

the Meeting, were held as read, were approved, and were thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Professor G. G. Henderson, M.A., D.Sc., delivered a lecture entitled, "Some Developments in Chemical Theory during the Nineteenth Century," being the second of the Centenary series. The lecture was illustrated by models, diagrams, and lantern slides.

A vote of thanks was passed to Professor Henderson on the motion of Mr George T. Beilby, seconded by Professor James Blyth.

4. The Chairman announced that the following gentlemen had been duly elected members of the Society:—

1. Mr ARTHUR KAY, J.P., Tregortha, Winton Drive.
2. Bailie JOHN KENNEDY, Airdrie.

27th January, 1904.

The Sixth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 27th January, 1904, at eight o'clock. In the absence of the President Mr William Ewing, Vice-President, occupied the Chair.

1. The Minute of Meeting, of date 13th January, 1904, having been printed in the Billet calling the meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. The Chairman here asked leave to vacate the chair in favour of Professor Andrew Gray, President of the Mathematical and Physical Section, as the papers about to be read were communications from that Section.

The Meeting having agreed to Mr Ewing's proposal, Professor Gray thereupon took the Chair and occupied it for the remainder of the evening.

4. Mr Charles E. Fawsitt, Ph.D., read a paper, with illustrations, on "The Viscosity of Aqueous Solutions." A discussion followed, in which part was taken by Mr Falconer, Professor Blyth, Mr H. S. Allen, the Chairman, and Dr Fawsitt.

5. Mr H. Stanley Allen, M.A., B.Sc., read the following notes on Physical Apparatus:—(*a*) "An apparatus for Illustrating the Composition of Velocities," (*b*) "An Electro-Plating Brush."

Professor Blyth, Professor Bennett, and the Chairman took part in the discussion which followed.

6. Mr W. E. Williams, B.Sc., read a paper, with lantern illustrations, on "The Stability of Flying Machines," which was followed by a discussion, in which Mr H. S. Allen, Mr Falconer, the Chairman, and Mr Williams took part.

The thanks of the Meeting were, on the motion of the Chairman, accorded to Dr Fawsitt, Mr Allen, and Mr Williams for their papers.

7. The Acting-Secretary announced that the following gentlemen had been duly elected Members of the Society:—

1. Mr JAMES A. ALLAN, Shipping Agent, 25 Bothwell Street.
2. Mr ROBERT GOURLAY, LL.D., Banker, 5 Marlborough Terrace.
3. Mr WILLIAM MACKINNON, C.A., 34 West George Street.

10th February, 1904.

The Seventh Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 10th February, 1904, at eight o'clock. The President, Professor Archibald Barr, occupied the Chair.

1. The Minute of Meeting, of date 27th January, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Mr George T. Beilby, F.I.C., Assoc. Inst. C.E., delivered the third of the series of Centenary Lectures, the subject being "Advances in Chemical Industry during the Nineteenth Century." The lecture was illustrated by the projection lantern, and specimens of chemical products were exhibited. On the motion of Mr William Ewing, seconded by Mr Charles A. Fawsitt, a vote of thanks was accorded to Mr Beilby.

4. The President announced that Mr Allan F. Baird, writer, 192 St Vincent Street, had been duly elected a member of the Society.

24th February, 1904.

The Eighth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 24th February, 1904, at eight o'clock. In the absence of the President, Dr A. K. Chalmers, President of the Sanitary and Social Economy Section, occupied the chair.

1. The Minute of Meeting, of date 10th February, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Member elected at the previous Meeting was duly admitted.

3. Dr James Devon, Prison Medical Officer, read a paper entitled, "The Treatment of the Criminal and Offender." The paper evoked considerable discussion, in which part was borne by Dr Neilson, Mr Todd, Dr Carswell, Dr M'Vail, Superintendent Douglas, Dr Moffat, Mr Aiton, Mr Grove, Dr Richmond, Dr Munro, Mr Munro, and Dr Chalmers. Dr Devon replied, and received the thanks of the Meeting on the motion of the Chairman.

4. Dr John Brownlee, Physician Superintendent, City of Glasgow Fever Hospital, Belvidere, read a paper entitled "Age

Incidence in Zymotic Diseases." The paper was illustrated by a large number of slides. Appreciative remarks on the paper were made by Dr Chalmers, Professor Bennett, Dr M'Vail, Mr G. Thomson, and Dr Buchanan. A vote of thanks was passed to Dr Brownlee, on the motion of the Chairman.

5. The Acting-Secretary announced that the following gentlemen had been duly elected Members of the Society.

1. Mr HARRY D. D. BARMAN, Engineer, 21 University Gardens.
2. Mr ALEXANDER CLEGHORN, 10 Whittinghame Drive, Kelvinside.
3. Mr ANDREW LAMBERTON, Blairtummock, Easterhouse.
4. Mr ROBERT THOMAS MOORE, Civil Engineer, 13 Claremont Gardens.
5. Mr JAMES RUSSELL, Engineer, c/o Cluness, 25 Woodside Quadrant.

9th March, 1904.

The Ninth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 9th March, 1904, at 8 o'clock. The President, Professor Archibald Barr, occupied the chair.

1. The Minute of Meeting of date 24th February, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Professor Robert Muir, M.A., M.D., delivered the fourth of the Centenary Series of Lectures, the subject being, "Some Advances in Medical Science during the Nineteenth Century." A large number of illustrative slides were shown.

At the close of the lecture a vote of thanks was accorded to Professor Muir on the motion of Dr. Yellowlees, seconded by Professor Glaister, and supported by the Chairman.

4. The Articles of Association (a copy of which had been sent to each member with the ninth billet) as amended by the Council were then submitted.

Mr Robert Goodwin proposed that clause 10 of Article xvi. should read, "No member shall be entitled to vote at any Meeting of the Society, whose Annual Subscription is more than six months in arrear."

Mr John F. Campbell proposed that the footnote on the first page of the Memorandum of Association, referring to the change of title, should include the date of His Majesty's command.

Mr Fred. G. Mackillop proposed that sub-clause (*b*) of clause 2, Article xvi. should be deleted, and that, after the word "exclude" this clause should read, "and (*b*) for the suspension of the Standing Orders."

The Meeting accepted these three amendments.

Mr John F. Campbell proposed an amendment of clause 6, Article xii., to define the word "immediately" occurring there; but the amendment was not accepted.

The Articles of Association thus amended were then approved on the motion of the Chairman, seconded by Dr Fergus, and it was remitted to the Council to do what was necessary in order to comply with the provisions of the Companies' Acts.

23rd March, 1904.

The Tenth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 23rd March, 1904, at eight o'clock. The President, Professor Archibald Barr, occupied the chair, and was supported by Dr George Neilson, President of the Philological and Historical Section.

1. The Minute of Meeting, of date 9th March, 1904, having been printed in the Billet calling the Meeting, was held as read.

The President, before submitting the Minute for confirmation, drew attention to an error it contained. He pointed out that clause 10, Article xvi., of the Articles of Association, as amended on the motion of Mr Robert Goodwin, should read—"No Member whose Annual Subscription is more than six months in arrear shall be entitled to vote at any Meeting of the Society," and moved that the correction be made. The meeting agreed, and with this alteration the Minute was approved, and was thereupon signed by the President.

2. Sir James D. Marwick, LL.D., F.R.S.E., read a paper entitled, "Some Observations on Primitive and Early Markets and Fairs," being a communication from the Historical and Philological Section.

A discussion followed in which, Dr Neilson, Mr Barrett, Bailie Graham, Mr John Clark, Mr Macindoe, and Mr Mayer, took part. Sir James Marwick replied, and on the motion of the President was accorded the thanks of the Meeting.

6th April, 1904.

An Extraordinary General Meeting of the Members of the Philosophical Society of Glasgow, having been duly convened, was held in the Rooms of the Society, 207 Bath Street, Glasgow, on the 6th day of April, 1904, at 7.50 p.m.

The Chair was occupied by the President, Professor Archibald Barr, D.Sc.

Present—A Quorum.

The following Special Resolutions, having been moved by the President and seconded by the Hon. Secretary, Dr Freeland Fergus, were duly passed:—

1. That His Majesty The King having expressed his approval of the word "Royal" being prefixed to the name of the Society, resolved that the name of the Society be changed to "The Royal Philosophical Society of Glasgow."

2. That the Regulations contained in the printed document submitted to the Meeting, and, for the purpose of identification, subscribed by the Chairman thereof, be, and the same are hereby approved; and that such Regulations be, and are hereby adopted as the Regulations of the Society; and that the same shall come into operation on the first day of January, 1905, to the exclusion of all the existing Regulations thereof.

Thereafter the Chairman signed the copy of the Articles of Association submitted.

6th April, 1904.

The Eleventh Ordinary Meeting, for Session 1903-04 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 6th April, 1904, at eight o'clock. The President, Professor Archibald Barr, occupied the chair.

1. The Minute of the previous Meeting, of date 23rd March, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. Mr Robert Caird, LL.D., delivered the fifth of the Centenary Series of Lectures, the subject being "Developments in the Means of Communication by Sea during the Nineteenth Century."

At the close of the lecture a vote of thanks was accorded to Dr Caird on the motion of Dr John Inglis, seconded by Mr James Mollison, and supported by the President.

3. The President announced that the following two gentlemen had been duly elected to Honorary Membership of the Society:—

1. *Foreign.*

D. IVANOVITSCH MENDELÉEFF, D.Phil. of St Petersburg, Professor of Chemistry in the University and in the Technological Institute of St Petersburg; Hon. President of the Russian Physico-Chemical Society; President of the Bureau of Weights and Measures, Hon. Foreign Fellow of the Royal Society of London, etc., 19 Zabalkansky, St Petersburg. Recommended by the Council.

2. *British.*

Sir William Huggins, K.C.B., D.C.L.Oxon., LL.D.Camb., Pres. R.S., F.R.A.S., etc., 90 Upper Tulse-Hill, London, S.W. Recommended by the Council.

MINUTE OF EXTRAORDINARY GENERAL MEETING OF DATE 27TH APRIL, 1904.

An Extraordinary General Meeting of the Members of the Philosophical Society of Glasgow, having been duly convened, was held in the Rooms of the Society, 207 Bath Street, Glasgow, on the 27th day of April, 1904, at 7.50 p.m.

The Chair was occupied by the President, Professor Archibald Barr, D.Sc.

Present—A Quorum.

The following Special Resolutions, having been duly passed at an Extraordinary Meeting held on 6th April, 1904, were duly confirmed on the motion of the President, seconded by the Hon. Secretary, Dr Freeland Fergus.

RESOLUTIONS.

(1) That His Majesty The King having expressed his approval of the word "Royal" being prefixed to the name of the Society, resolved that the name of the Society be changed to "The Royal Philosophical Society of Glasgow."

(2) That the Regulations contained in the printed document submitted to the Meeting, and, for the purpose of identification, subscribed by the Chairman thereof, be, and the same are hereby approved; and that such Regulations be, and they are hereby adopted as the Regulations of the Society; and that the same shall come into operation on the first day of January, 1905, to the exclusion of all the existing Regulations thereof.

27th April, 1904.

The Twelfth Ordinary Meeting, for Session 1903-1904 of the Royal Philosophical Society of Glasgow, was held within the

Rooms, 207 Bath Street, on the evening of Wednesday, 27th April, 1904, at eight o'clock. The President, Professor Archibald Barr, occupied the chair.

1. The Minutes of an Extraordinary Meeting, and of the previous Ordinary Meeting, both of date 6th April, 1904, having been printed in the Billet calling the Meeting, were held as read, were approved, and were thereupon signed by the Chairman.

2. Professor D. Ivanovitsch Mendeléeff and Sir William Huggins were admitted to Honorary Membership of the Society *in absentia.*

The Honorary Secretary read the following letters of acknowledgement from these gentlemen:—

ST PETERSBOURG,
19th April, 1904.

DEAR SIR,

Your very kind letter—announcing that the Royal Philosophical Society of Glasgow has elected me an Honorary Member—I have received, and beg you to accept and convey to the Royal Philosophical Society of Glasgow my sincerest and deepest thanks for the great honour shown to me.

Yours very truly,

D. MENDELÉEFF.

To Dr FREELAND FERGUS, Hon. Secy.
of the Royal Philosophical Society of
Glasgow, 207 Bath Street.

90 UPPER TULSE HILL, S.W.,
14th April, 1904.

DEAR SIR,

I desire through you, as Honorary Secretary, to return my sincere thanks to the Council and Members of the Royal Philosophical Society of Glasgow, and to assure them of my warm appreciation of the high honour they have conferred upon me by electing me one of their Honorary Members.

I prize very greatly the distinction of belonging to your Society which, for more than a century, has taken a most worthy place in science and philosophy.

I thank you personally for the courtesy of your communication.

I remain,

Yours very faithfully,

WILLIAM HUGGINS.

Dr Fergus,
Hon. Secretary.

It was agreed that these letters should be engrossed in the Minute book.

3. Mr Sampachi Fukuzawa read a paper entitled "The Future of Japan from a Geographical point of view," being a communication from the Geographical and Ethnological Section.

Mr Falconer, Mr Ewing, Mr Sam Mavor, Mr Jolly, and and Professor Barr took part in a discussion which ensued.

Mr Fukuzawa replied, and was accorded a vote of thanks on the motion of the Chairman.

4. Mr Peter Macnair, keeper of the Natural History Collections in the Glasgow Museums, and Joint Secretary of the Glasgow Geological Society, read a paper entitled "Notes on Pseudogaylussite dredged from the Clyde at Cardross, and other recent additions to the mineral collections at Kelvingrove Museum."

Geological specimens were exhibited and lantern slides shown in illustration of the paper.

Mr French made some remarks on the paper, and the thanks of the meeting were accorded to Mr Macnair on the motion of the Chairman.

5. The Hon. Secretary intimated that Mr Walter M. N. Reid, 10 Woodside Terrace, Glasgow, had been duly elected to Membership of the Society.

6. The Minute of an Extraordinary Meeting of the Society, held immediately before the Ordinary meeting of this date, was read by the Acting Secretary, was approved, and the Chairman authorised to sign it when it should be engrossed in the Minute book.

7. This Minute having been read to the meeting by the Acting-Secretary, was approved, and the Chairman authorised to sign it when it should be engrossed in the Minute book.

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OF THE

Royal Philosophical Society of Glasgow.

SESSION 1903-1904.

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Professor PETER BENNETT, *Acting Secretary.*

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* *Retire by rotation in November, 1904.*

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(In abeyance.)

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(In abeyance.)

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Dr Fergus.
John Mann, Jun.
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John Mann.

John Mann, *Convener.*

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Professor Walter Raleigh.
Professor Ferguson.
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A. E. Scougal.
The Right Hon. Lord Inverclyde
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Ninian Macwhannell.
Gilbert Thomson.
Professor Walter Raleigh.
Wm Ewing.
Professor Maclean.
Dr Caird.
Dr Chalmers.
Robert Blyth.
George Neilson.
Geo. T. Beilby.
H. A. Mavor.
Professor Gray.
James Knight.
John Robertson.
John A. Todd.
A. E. Scougal.
Dr Fergus.
John Mann, Jun.
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Dr Fergus, *Convener.*

Science Lecture Trust and Graham Medal Fund Committee.

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Professor M'Kendrick.
Professor Gray.
Professor M. Maclean.
Dr Fergus.
Professor Ferguson.
Professor R. S. Thomson.
H. A. Mavor.
Geo. T. Beilby.
The Rt. Hon. Lord Inverclyde.

Professor Maclean, *Convener.*

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Institution of Engineers and Shipbuilders in Scotland.

Archibald Denny.
James Gilchrist.
George M'Farlane.
A. W. Sampson.
C P. Hogg.
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Royal Philosophical Society.

Professor Barr.
John Mann.
John Robertson.
Professor Bennett.
Geo. Neilson.
John Mann. *Treasurer.*

ADDITIONS TO THE LIBRARY.

By Donation.

From Dr Henry Dyer—
  Twenty-eighth Annual Report of the Minister of State for Education, Japan, 1900-01.

From Dr A. Campbell Munro (Author)—
  Annual Reports upon the Health and Sanitary Condition of the County of Renfrew for 1897, 98, 99, 1900, 01, and 1902.

From Dr C. R. Macdonald (Author)—
  Annual Reports upon the Health and Sanitary Condition of the County of Ayr for 1891, 99, and 1902.
  Soil in Relation to Health. Glasgow, 1894. Pamphlet.

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From Dr A. K. Chalmers—

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From Dr James Finlayson—

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From the Publishers—

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From Mr Nathaniel Dunlop—

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From Dr Freeland Fergus—

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From Mr James Paton—
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From Dr John T. Wilson—
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From Mr Peter Fyfe—
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THE ROYAL PHILOSOPHICAL SOCIETY EXCHANGES WITH THE FOLLOWING SOCIETIES, ETC.:—

AFRICA.

Cape Town—
- South African Association for the Advancement of Science.
- Cape of Good Hope Observatory. The Astronomer Royal.
- South African Philosophical Society.

Pretoria—
- Transvaal Department of Agriculture.

AUSTRALIA.

Brisbane—
- Royal Geographical Society of Australasia.

Melbourne—
- Royal Observatory Library.
- Royal Society of Victoria, Victoria Street.

AUSTRALIA—*continued.*

Sydney—
Geological Survey, Department of Mines and Agriculture.
Royal Society of New South Wales, 5 Elizabeth Street, North.
Technological Museum.
Royal Anthropological Society of Australasia.
Australian Association for the Advancement of Science. The University.
Australian Museum.
University Library.

BELGIUM.

Brussels—
Académie Royale des Sciences.
Observatoire Royale.
Société Royale Malacologique de Belgique. 14 Rue des Sols.

Liège—
Société Royal des Sciences.

BRAZIL.

Rio de Janeiro—
Museu Nacional do Rio de Janeiro.

CANADA.

Halifax—
Nova Scotian Institute of Science.

Hamilton (Ont.)—
Hamilton Association.

London (Ont.)—
Entomological Society of Ontario.

Montreal—
Canadian Society of Civil Engineers, 112 Mansfield Street.

Ottawa—
Geological Survey of Canada, Sussex Street.
Royal Society of Canada.

Quebec—
Literary and Historical Society of Quebec.

Regina—
Department of Agriculture, North-West Territories.

Toronto—
Canadian Institute, 58 Richmond Street, East.

Winnipeg—
Manitoba Historical and Scientific Society.

CHINA.

Hong Kong—
Hong Kong Observatory.

ENGLAND AND WALES.

Barnsley—
Midland Institute of Mining, Civil, and Mechanical Engineers, Elder Street.

Bath—
Bath Natural History and Antiquarian Field Club. Royal Literary Institution.

Birmingham—
Philosophical Society, Medical Institute, Edmund Street.

Bristol—
Bristol Naturalists' Society. Dr C. K. Rudge, Ashgrove House, 145 White Ladies' Road, Clifton.

Cambridge—
Philosophical Society, New Museum.
University Library. The Curator.

Cardiff—
Cardiff Naturalists' Society, Dr Griffith, 50 Newport Road.
South Wales Institute of Engineers, Park Place.

Falmouth—
Royal Cornwall Polytechnic Society.

Greenwich—
Royal Observatory. The Astronomer Royal.

Leicester—
Leicester Literary and Philosophical Society.

Liverpool—
Geological Society, Royal Institution, Colquitt Street.
Literary and Philosophical Society. Tate Librarian, University College.
Liverpool Engineering Society, Royal Institution, Colquitt Street.

London—
Anthropological Institute, 3 Hanover Square.
British Association for the Advancement of Science, Burlington House.
British Museum. The Superintendent, Copyright Office.
Chemical Society, Burlington House.
Electrical Publishing Co., Ltd., 4 Southampton Row, Holborn, W.C.
Engineering. The Publisher, 35 Bedford Street, Strand.
Institution of Civil Engineers, Great George Street, Westminster, S.W.
Institution of Mechanical Engineers, Storey's Gate, St. James' Park, Westminster.
Junior Institution of Engineers, 39 Victoria Street, Westminster, S.W.
Patent Office Library, 25 Southampton Buildings, Chancery Lane.
Pharmaceutical Society, 17 Bloomsbury Square.
Royal Geographical Society, 1 Saville Row.
Royal Institute of British Architects, 9 Conduit Street, Hanover Square.
Royal Institution of Great Britain and Ireland, Albemarle Street, Piccadilly, W.
Royal Meteorological Society, 22 Great George Street, Westminster.

ENGLAND AND WALES—*continued.*

London—*continued.*
Royal Photographic Society, 66 Russell Square, W.
Royal Society, Burlington House.
Royal Statistical Society, 9 Adelphi Terrace, Strand.
Society of Arts, John Street, Adelphi.
Society of Biblical Archæology, 37 Great Russell Street, Bloomsbury.
Society of Chemical Industry, Palace Chambers, 9 Bridge Street, Westminster.
Society of Psychical Research, 19 Buckingham Street.

Manchester—
Manchester Association of Engineers, Grand Hotel, Aytoun Street.
Geographical Society, 16 St Mary's Parsonage.
Literary and Philosophical Society of Manchester, 36 George Street.

Middlesborough—
Cleveland Institution of Engineers.

Newcastle-upon-Tyne—
North-East Coast Institution of Engineers and Shipbuilders, 4 St Nicholas Buildings.
North of England Institute of Mining and Mechanical Engineers, Neville Hall.

Oxford—
Bodleian Library.

Stratford (Essex)—
Essex Field Club. Passmore-Edwards Museum, Romford Road.

Truro—
Royal Institution of Cornwall.

Watford—
Hertfordshire Natural History Society and Field Club (Endowed Schools).

Welshpool—
Powys-Land Club. The Secretaries, Museum and Library, Salop Road.

FRANCE.

Bordeaux—
Société des Sciences Physiques et Naturelles de Bordeaux.

Marseilles—
Faculté des Sciences de Marseille.

Paris—
École Polytechnique. The Director.
Observatoire Météorologique Central de Montsouris.

Rennes—
Library of the University.

GERMANY.

Berlin—
Deutsche Chemische Gesellschaft.

GERMANY—*continued.*

Berlin—*continued.*
- Deutsche Kolonial Verein.
- Königliche Preussische Akademie der Wissenchaften.

Bremen—
- Geographische Gesellschaft.

Giessen (Hesse)—
- Oberhessische Gesellschaft für Natur-und-Heilkunde.

Griefswald (Prussia)—
- Geographische Gesellschaft.

Halle (Prussia)—
- Vereins für Erdkunde zu Halle.
- Kaiserliche Leopoldino—Carolinische Deutsche Akademie der Naturforscher.

INDIA.

Calcutta—
- Geological Survey of India.

IRELAND.

Belfast—
- Belfast Naturalists' Field Club, Museum, College Square, North.
- Natural History and Philosophical Society, Museum, College Square, North.

Dublin—
- Royal Dublin Society, Leinster House.
- Royal Irish Academy, 19 Dawson Street.
- Trinity College Library.

ITALY.

Milan—
- Reale Instituto di Lombardo di Scienze, Lettere, ed Arti.

JAPAN.

Kyōto—
- Imperial University, College of Science and Engineering.

Tokio—
- Imperial University of Tokio, Science College.

JAVA.

Batavia—
- Royal Magnetical and Meteorological Observatory.

MEXICO.

Mexico—
- Instituto Geologico de Mexico.
- Observatorio Astronómico Nacional de Tacubaya.
- Observatorio Meteorologico-Magnetico Central.
- Sociedad Científica "Antonio Alzate."

MONACO.

Monaco—
  Musée Océanographique.

NETHERLANDS.

Amsterdam—
  Académie Royale des Sciences à Amsterdam.
Harlem—
  Musée Teyler.
  Société Hollandaise des Sciences à Harlem.
Leyden—
  Kon. Nederlandisch Aardrijkskundig Genootschap.

NEW ZEALAND.

Wellington—
  New Zealand Institute.

NORWAY.

Christiania—
  Kongelige Norske Frederiks Universitet.
  Videnskabs-Selskabet i Christiana.

ROUMANIA.

Bucharest—
  Societatiĭ de Sciinte Fizice.

RUSSIA.

Kazan—
  Imperial Kazan University.
St. Petersburg—
  Académie Impériale des Sciences.

SCOTLAND.

Aberdeen—
  Philosophical Society, 147 Union Street.
Alnwick—
  Berwickshire Naturalists' Club, *per* George Bolaur.
Edinburgh—
  Advocates' Library.
  Botanical Society of Edinburgh, Royal Botanic Garden.
  Geological Society, 5 St Andrew Square.
  Highland and Agricultural Society of Scotland, 3 George IV. Bridge.
  Royal Physical Society, 18 George Street.
  Royal Scottish Geographical Society, Queen Street.
  Scottish Meteorological Society, 122 George Street.
  Royal Scottish Society of Arts, 117 George Street.
  Royal Society, The Mound, Princes Street.

SCOTLAND—*continued.*

Glasgow—
- Archæological Society, 88 West Regent Street.
- Baillie's Institution Free Library.
- Faculty of Physicians and Surgeons of Glasgow, 242 St Vincent Street.
- Geological Society, 207 Bath Street.
- Glasgow and West of Scotland Technical College Library, 38 Bath Street.
- Institution of Engineers and Shipbuilders in Scotland, 207 Bath Street.
- Mitchell Library, Miller Street.
- Natural History Society of Glasgow, 207 Bath Street.
- Stirling's Public Library, Miller Street.
- West of Scotland Iron and Steel Institute.

Hamilton—
- Mining Institute of Scotland.

SWEDEN.

Upsala—
- Royal University Library.

Stockholm—
- Kongliga Svenska Vetenskaps-Akademie.

TASMANIA.

Hobart—
- Royal Society of Tasmania.

UNITED STATES.

Albany—
- New York State Department of Health.
- New York State Library.

Austin (Texas)—
- Texas Academy of Science.

Baltimore—
- Johns Hopkins University.

Berkeley (Cal.)—
- University of California.

Boston—
- American Academy of Arts and Sciences.
- Boston Society of Natural History.

Buffalo—
- Buffalo Society of Natural Sciences.

Chicago—
- Western Society of Engineers.

Colorado Springs—
- Coburn Library, Colorado College.

Columbia (Mo.)—
- University of Missouri.

UNITED STATES—*continued.*

Davenport (Iowa)—
  Academy of Natural Sciences.

Denver—
  Colorado Scientific Society.

Des Moines (Iowa)—
  Iowa Geological Survey.

Indianopolis (Ind.)—
  Indiana Academy of Science.

Lawrence (Kansas)—
  Kansas University.

Madison (Wis.)—
  Madison Geological and Natural History Society.
  Washburn Observatory.

Mount Hamilton (Cal.)—
  Lick Observatory.

Newhaven (Conn.)—
  Connecticut Academy of Arts and Sciences.
  Yale University.

New York—
  American Geographical Society, 15 Eighty-first Street.
  American Museum of Natural History, Seventy-seventh Street, and Central Park West.
  American Society of Civil Engineers, 220 West Fifty-seventh Street.
  New York Academy of Sciences Library, Seventy-Seventh Street, Central Park, West.
  School of Mines, Columbia College. The Associate Editor.

Philadelphia—
  Academy of Natural Science of Philadelphia.
  The Associated Alumni of the Central High School of Philadelphia.
  American Pharmaceutical Association.
  American Philosophical Society. The Hon. Secretaries, 104 South Fifth Street.
  Franklin Institute, 15 South Seventh Street.
  Numismatic and Antiquarian Society of Philadelphia.
  Wagner Free Institute of Science, corner of Seventeenth Street and Montgomery Avenue.

Rochester (N.Y.)—
  Rochester Academy of Science. Corresponding Secretary.

St. Louis—
  Academy of Science of St Louis.
  Missouri Botanical Garden.

Salem—
  American Association for the Advancement of Science.

San Francisco (California)—
  California Academy of Sciences.

UNITED STATES—*continued.*

Topeka (Kansas)—
  Kansas Academy of Science.

Washington—
  Bureau of Education (Department of the Interior).
  Bureau of Ethnology.
  Smithsonian Institution.
  United States Geological Survey.
  United States National Museum (Department of the Interior).
  United States Naval Observatory.
  United States (Department of Agriculture).

LIST OF PERIODICALS.

(Those received in exchange are indicated by an "a").

WEEKLY.

Academy.
Architect.
Athenæum.
British Journal of Photography.
Builder.
Building News.
Chemical News.
Comptes Rendus.
County and Municipal Record.
*a*Deutsche Kolonialzeitung.
Dingler's Polytechnisches Journal.
Electrical Review.
Electrician.
*a*Engineering.
English Mechanic.
*a*Illustrated Official Journal of Abridgements of Patents.
*a*Journal of the Society of Arts.
Journal of Gas Lighting.
Lancet.
La Nature.
Nature.
Notes and Queries.
*a*Pharmaceutical Journal.
*a*Publishers' Circular.
Scientific American and Supplement.
Zeitschrift für Angewandte Chemie.

FORTNIGHTLY.

Annalen der Chemie (Liebig's).
*a*Berichte der Deutschen Chemischen Gesellschaft.
Journal de Pharmacie et de Chimie.
Journal für Praktische Chemie.

MONTHLY.

*a*American Chemical Journal.
American Journal of Science.
Analyst.
Annalen der Physik.
Annales de Chimie et de Physique.
Annales de l'Institut Pasteur.
Annales des Mines.
Annales des Ponts et Chaussées.
Annales des Sciences Naturelles—Botanique.
Annales des Sciences Naturelles—Zoologie.
Annals and Magazine of Natural History.
Antiquary.
Beiblätter zu den Annalen der Physik.
Bulletin de la Société Chimique de Paris.
Bulletin de la Société Géologique de France.
Bulletin de la Société Industrielle de Mulhouse.
Bulletin de la Société d'Encouragement pour l'Industrie Nationale.
Bulletin of the American Mathematical Society.
*a*Canadian Entomologist.

MONTHLY—*continued.*

*a*Engineering Magazine.
*a*Electrical Magazine.
*a*Geographical Journal.
Geological Magazine.
*a*Johns Hopkins University Circulars.
Journal of Botany.
*a*Journal of the Chemical Society.
Journal of Education.
*a*Journal of the Franklin Institute.
*a*Journal of the Royal Photographic Society.
*a*Journal of the Society of Chemical Industry.
*a*Journal of the Western Society of Engineers.
Library Association Record.
Library World.
London, Edinburgh, and Dublin Philosophical Magazine.
Petermanns Mitteilungen.
Polytechnic Bibliothek.
*a*Proceedings of the Royal Society of London.
*a*Proceedings of the Society of Biblical Archæology.
Revue Universelle des Mines.
*a*Royal Astronomical Society's Monthly Notices.
Science Abstracts.
*a*Science of Man.
*a*Scottish Electrician.
*a*Scottish Geographical Magazine.
*a*Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
*a*Technics.
*a*Tijdschrift van het Koninklijk Nederlandoch Aardrijkskundig Genootschap.
*a*Travel.
Zoologist.

QUARTERLY.

Annals of Botany.
Annals of Scottish Natural History.
*a*Archives Néerlandaises des Sciences Exactes et Naturelles.
*a*Bulletin of the American Geographical Society.
*a*Bulletin of the Kansas University.
Economic Journal.
Englische Studien.
Jahrbuch über die Forschritte der Mathematik.
Journal of Anatomy and Physiology.
*a*Journal of the Anthropological Institute of Great Britain.
*a*Journal of Manchester Geographical Society.
*a*Journal of the Royal Institute of British Architects.
Journal of the Royal Microscopical Society.
*a*Journal of the Royal Statistical Society.
*a*Journal of the Scottish Meteorological Society.
*a*Memorias Y Revista de la Sociedad Científica "Antonio Alzate."
Mind: a Quarterly Review of Psychology and Philosophy.
*a*Proceedings of the American Philosophical Society.
Quarterly Journal of Economics.
Quarterly Journal of Geological Society.
Quarterly Journal of Microscopical Science.
*a*Quarterly Journal of Royal Meteorological Society.
Quarterly Journal of Pure and Applied Mathematics.
Reliquary and Illustrated Archæologist.
Record of Technical and Secondary Education.
Revue Historique.
*a*School of Mines Quarterly.
Scottish Historical Review.
Scientific Roll.
Zeitschrift fur Analytische Chemie.

ANNUALLY.

- Association Française pour l'Avancement des Sciences.
- British Journal Photographic Almanac.
- Hazell's Annual.
- Jahres-Bericht Chemischen Technologie.
- Journal of the Royal Agricultural Society of England.
- L'Année Scientifique et Industrielle.
- Murray's English Dictionary.
- *a*Journal de L'École Polytechnique.
- Palæontographical Society's Publications.
- Philosophical Transactions, Royal Society of London.
- Ray Society's Publications.
- Repertorium der Technischen Journal—Litteratur.
- Report of the Board of Education.
- Statesman's Year Book.
- Symons' British Rainfall.
- Wright's English Dialect Dictionary.

The LIBRARY and the READING-ROOM are open:—Winter, 9.30 a.m. till 10 p.m. (except Saturdays); Saturdays, till 2 p.m.

Summer (May till October, except during the holidays, from the 11th till 31st July), 9.30 a.m. till 5 p.m.; Saturdays, till 1 p.m.

LIST OF MEMBERS

OF THE

Royal Philosophical Society of Glasgow

FOR 1903-1904.

HONORARY MEMBERS.

(*Limited to Twenty.*)

WITH YEAR OF ELECTION.

FOREIGN.

	Rudolph Albert von Kölliker, Würzburg.	1860
	Professor Ernst Heinrich Hæckel, Jena.	1880
	Professor Georg Quincke, Hauptstrasse 47, Friederichsbau, Heidelberg.	1890
	D. Ivanovitsch Mendeléeff, 19 Zabalkansky, St Petersburg.	1904

AMERICAN AND COLONIAL.

5	Robert Lewis John Ellery, F.R.A.S., Victoria, Australia.	1874
	Thomas Muir, M.A., LL.D., F.R.S.S., L. and E., Superintendent General of Education, Cape Colony.	1892
	Professor S. P. Langley, LL.D., D.C.L., Secretary of the Smithsonian Institution, Washington, U.S.A.	1895

BRITISH.

	Sir Joseph Dalton Hooker, C.B., G.C.S.I., M.D., D.C.L., LL.D., F.R.S., The Camp, Sunningdale.	1874
	Rev. John Kerr, LL.D., F.R.S., Glasgow.	1885
10	The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.S.G., Prof. of Nat. Philosophy in the Royal Institution, London, Terling place, Witham, Essex.	1890
	The Right Hon. Lord Lister, O.M., LL.D., D.C.L., F.R.S., 12 Park crescent, Portland place, London, W.	1895
	Sir Archibald Geikie, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom, 10 Chester terrace, Regent's Park, London, N.W.	1895
	The Right Hon. Lord Kelvin, O.M., G.C.V.O., LL.D., D.C.L., F.R.S., Largs. (*Ordinary Member*, 1846 *till* 1896.)	1896
	James B. Russell, LL.D., M.D., 49 Braid road, Morningside, Edinburgh, *Honorary Vice-President*,	1899
15	Sir William T. Gairdner, K.C.B., M.D., LL.D., F.R.S., George sq., Edinburgh. (*Ordinary Member*, 1863 *till* 1900.)	1900
	Professor Edward Albert Schäfer, LL.D., F.R.S., M.R.C.S., University of Edinburgh.	1902
	Sir William Huggins, K.C.B., D.C.L.Oxon., LL.D.Camb., Pres. R.S., F.R.A.S., etc., 90 Upper Tulse-hill, London, S.W.	1904

CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

	A. S. Herschel, M.A., D.C.L., F.R.S., F.R.A.S., Hon. Professor of Experimental Physics in the University of Durham; Observatory House, Slough, Bucks.	1874
	Thomas E. Thorpe, Ph.D., F.R.S., F.R.S.E., Principal of the Government Laboratories, Clement's Inn-passage, W.C.	1874
	John Aitken, LL.D., F.R.S., F.R.S.E., Ardenlea, Falkirk.	1883
	Alex. Buchan, M.A., LL.D., F.R.S.E., F.R.S., Secretary to the Scottish Meterological Society, 122 George street, Edinburgh.	1883
5	James Dewar, M.A., F.R.S., F.R.S.E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, 1 Scroope terrace, Cambridge.	1883
	Joseph W. Swan, M.A., F.R.S., 58 Holland Park, W.	1883
	William Milne, M.A., B.Sc., F.R.S.E., Department of Public Education, Cradock, Cape Colony.	1894
	Richard Lodge, M.A., Professor of History in Edinburgh University.	1899
	Edmund J. Mills, D.Sc., LL.D., F.R.S., Emeritus Professor of Technical Chemistry, Glasgow and West of Scotland Technical College, 11 Greenhill road, Harrow.	1901
10	Arthur Schuster, Ph.D., F.R.S., Professor of Physics, Victoria University, Manchester, Victoria park, Manchester.	1901
	W. S. M'Cormick, M.A., LL.D., 2 St Andrew's square, Edinburgh.	1902
	John George Bartholomew, F.R.S.E., F.R.G.S., Geographical Institute, Park road, Edinburgh.	1902
	James Burgess, C.I.E., LL.D., F.R.S.E., Hon. A.R.I.B.A., F.R.G.S., 22 Seton place, Edinburgh.	1902
	Francis Elgar, LL.D., F.R.S., F.R.S.E., 18 Cornwall Terrace, Regent's park, London, N.W.	1902
15	Frederick Emley, Literary and Philosophical Society of Newcastle-upon-Tyne.	1902
	Professor Cargill G. Knott, D.Sc., F.R.S.E., 42 Upper Gray street, Edinburgh.	1902
	Principal John Yule Mackay, M.D., LL.D., University College, Dundee.	1902
	Professor John Millar Thomson, LL.D., F.R.S., F.I.C., F.C.S., King's College, and 85 Addison road, London.	1902
	Professor Robert Wallace, F.R.S.E , F.L.S., F.C.S., University of Edinburgh.	1902

ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

a Denotes Life Members.

	Adam, Stephen, 121 Bath street.	1896
	*a*Adam, Thomas, F.S.I., 27 Union street.	1892
	Adams, John, M.B., 1 Queen's crescent, W.	1902
	Adams, William, Makerstoun, Bearsden.	1891
5	Addison, W. H., Superintendent Mount Florida Deaf and Dumb Institution.	1895
	*a*Agar, Thomas F., Argentine Consul-General, 30 George square.	1896
	Agnew, John, Viewfield, Carluke.	1901
	Aikman, W. G., 12 Kingsborough gardens, Kelvinside.	1899
	Aiton, Alexander Hamilton, 190 West George street.	1902
10	Alexander, D. M., 5 Derby crescent, Kelvinside.	1887
	Alexander, G. W., M.A., 129 Bath street.	1893
	Allen, Herbert Stanley, M.A., B.Sc., Blythswood laboratory, Renfrew.	1901
	*a*Allan, Henry, 2 Park gardens.	1900
	*a*Allan, James A., 25 Bothwell street.	1904
15	Allan, James W., M.B., 18 India street.	1900
	Alison, John, M.A., F.R.S.E., U.F.C. Training College.	1903
	Alston, J. Carfrae, 9 Lorraine gardens.	1887
	Anderson, Alexander, 157 Trongate.	1869

Anderson, David H., Atlantic Mills, Bridgeton. 1904
20 Anderson, James, 4 Kingsborough gardens. 1900
Anderson, James, 168 George street. 1890
Anderson, James Scott, Auchnasith, Bearsden. 1902
Anderson, James Spencer, 81 Great Clyde street. 1901
Anderson, John, 142 West Nile st. 1884
25 Anderson, J. B. Mackenzie, M.B., 8 Buckingham terrace, Hillhead. 1895
Anderson, R. T. R., 80 Seedhill rd, Paisley. 1889
Anderson, Robert, 76 Bath street. 1896
Anderson, Robert, Eastwoodhill, Giffnock. 1900
*a*Anderson, Robert Locke, 233 St Vincent street. 1901
30*a*Anderson, T. M'Call, M.D., Professor of Practice of Medicine in the University of Glasgow, 9 The College. 1873
Anderson, Wm, 12 Princes square. 1900
*a*Anderson, William, 133 Wellington street. 1890
Anderson, W. F. G., 47 Union st. 1878
Andrew, Grant, 12 Woodside ter. 1900
35*a*Andrew, James, 160 West George street. 1900
Andrews, H. W., 140 Hyndland road, Kelvinside. 1902
Angus, Robert, Lugar, Ayrshire, N.B. 1901
*a*Annan, J. Craig, 518 Sauchiehall st. 1888
Annandale, Charles, M.A., LL.D., 35 Queen Mary avenue. 1888
40 Arneil, Allan, Stewarton drive, Cambuslang. 1901
*a*Arnot, J. L., 204 Bath street. 1890
Arrol, Theodore A., Torwood Hill, Row, Dumbartonshire. 1902
Arrol, William A., Torwoodhill, Row. 1869
*a*Arrol, Sir William, LL.D., Seafield, Ayr. 1900
45*a*Arthur, Andrew, 78 Queen street. 1902
*a*Arthur, James, 78 Queen street. 1900
Arthur, Sir Matthew, Bart., 78 Queen street. 1900
Arthur, Thomas G., Carrick house, Ayr. 1900

Bain, Andrew, 17 Athole gardens. 1890
50 Bain, Robert, 132 West Nile street. 1869
Baird, Allan F., 192 St. Vincent st. 1904
*a*Baird, J. G. A., M.P., Wellwood, Muirkirk. 1892
*a*Balfour, Alexander, Kelvindare, Kelvinside. 1900
Ballantine, George, jun., 100 Union street. 1897
55 Balmain, Thos, 1 Kew terrace, Kelvinside. 1881
Barbour, Wm, M.B., C.M., 3 Edelweiss terrace, Partick. 1900
Barclay, A. J. Gunion, M.A., F.R.S.E., High School. 1893
Barclay, A. P., 133 St Vincent street. 1890
Barclay, George, 8 Windsor circus. 1891
60 Barclay, James, 16 Roxburgh street, Kelvinside. 1871
Barman, Harry D.D., 21 University gardens. 1904
Barnet, John, 55 Oswald street. 1901
*a*Barr, Archibald, D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow, Royston, Dowanhill, *President.* 1890
*a*Barr, James, C.E., I.M., F.S.I., 221 West George street. 1883
65 Barr, Patrick, 51 Bath street. 1902
Barr, Thos, M.D., F.F.P.S.G., 13 Woodside place, W. 1879
Barrett, Francis Thornton, Mitchell Library. 1880
Bauermeister, F., 49 Gordon street. 1901
Baxter, John, I.M., 243 St Vincent street. 1901
70 Baxter, W. R., 64 Great George street, Hillhead. 1900
Bayne, A. Malloch, 13 Kelvin drive, Kelvinside. 1878
Beardmore, W., Parkhead Forge. 1901
Beatson, George T., B.A. (Cantab.), M.D., 7 Woodside crescent. 1881
Becker, L., Ph.D., Professor of Astronomy in the University of Glasgow, The Observatory. 1895
75 Beckett, Charles E., M.A., LL.B., 163 St Vincent street. 1903
Beckett, William, M.A., 225 West George street. 1900
Beedle, Peter D. Ridge, 166 Buchanan street. 1902
Begg, Wm, 636 Springfield road. 1883
Beilby, George T., F.I.C., 11 University gardens, Hillhead. 1895
80*a*Beith, Gilbert, 15 Belhaven terrace. 1881
Belhaven and Stenton, The Right Hon. Lord, Wishaw House, Wishaw. 1901
Bell, George, architect, 212 St Vincent street. 1900
*a*Bell, Henry, Mynthurst, Reigate, Surrey. 1876
Bell, Sir James, Bart, 135 Buchanan street. 1877
85*a*Bell, James T., Woodbine, Blairmore, Argyleshire. 1896
*a*Bell, John J., Woodbine, Blairmore, Argyleshire. 1896
*a*Bennett, Professor Peter, *Acting Secretary*, 207 Bath street. 1900

Bennett, Robert J., Savoy park, Ayr. 1883
Bergius, Walter, C.E., 77 Queen st. 1897
90 *a*Biggart, Thomas, 105 West George street. 1900
Bilsland, William, 28 Park circus. 1888
Binnie, Thomas, Junr., M.A., 3 Park Gate. 1903
*a*Birkmyre, John, Broadstone, Port-Glasgow. 1900
*a*Bishop, A. Henderson, Burncroft, Thorntonhall. 1896
95 Black, J. Albert, Lagarie, Row. 1869
Black, Malcolm, M.D., 5 Canning place. 1880
*a*Black, William Dunn, J.P., Auchentoshan, Dalmuir. 1901
*a*Blackie, J. Alexander, 17 Stanhope street. 1881
*a*Blackie, J. Robertson, North Bank, Dowanhill. 1881
100 Blackie, W. G., Ph.D., LL.D., F.R.G.S., 1 Belhaven terrace, Kelvinside. 1841
*a*Blackie, Walter W., B.Sc., The Hill House, Helensburgh. 1886
Blackwood, Matthew, Ardmore, Port-Glasgow. 1901
Blair, J. M'Lellan, Williamcraig, Linlithgowshire. 1869
Blair, Matthew, Moorings, Thornly Park, Paisley. 1887
105 Blair, William, 24 St Vincent place. 1902
Blyth, Jas, M.A., LL.D., F.R.S.E., Professor of Natural Philosophy, Glasgow and West of Scotland Technical College, 204 George street. 1881
*a*Blyth, Robert, 1 Montgomerie quadrant. 1885
*a*Blythswood, The Rt Hon. Lord, Renfrew, *Hon. Vice-President.* 1885
Borthwick, James D., 46 Balshagray avenue, Partick. 1891
110 *a*Boston, Alex. L., 12 Argyle arcade. 1902
Bottomley, James T., M.A., D.Sc., F.R.S., F.R.S.E., F.C.S., 13 University gardens, Hillhead. 1880
Bottomley, Wm, C.E., 15 University gardens. 1880
Bower, F.O., D.Sc., M.A., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow, 1 St John's terrace, Hillhead. 1885
*a*Boyne, James, 106 West Nile street. 1901
115 Boyd, John, Shettleston Iron-works, near Glasgow. 1873
*a*Broadfoot, William R., Inchholme Works, Whiteinch. 1900
Brodie, Wm Brodie, M.B., C.M., Worcestershire Sanatorium, Knightwick, near Worcester. 1897
Brodie, William, B.L., 77 St Vincent street. 1902
Bromhead, Horatio K., F.R.I.B.A., I.A., 18 Kirklee road, Kelvinside. 1901
120 Brown, Alex., The Craigs, Carmunnock. 1896
Brown, A. M., 22 West Nile street. 1900
Brown, George Arbuckle, M.B., C.M., D.P.H.(Camb.), 463 Dumbarton road, Partick. 1900
*a*Brown, Hugh, 5 St John's terrace, Hillhead. 1887
Brown, James, 76 St Vincent street. 1876
125 Brown, John Armour, Moredun, Paisley. 1901
Brown, J. T. T., Kessiebank, Cambuslang. 1902
*a*Brown, Nicol Paton, 22 Belhaven terrace. 1901
Brown, Richard, Professor of Mercantile Law, St Mungo's College, 166 St Vincent street. 1895
Brown, Robert, 19 Jamaica street. 1882
130 Brown, Thomas Mathieson, coalmaster, Ardnith House, New Cumnock, Ayrshire. 1901
Brown, Wm, F.S.A.A., F.S.I., 138 West Regent street. 1901
*a*Brown, Wm Stevenson, 67 Washington street. 1886
*a*Brown, William, 165 West George street. 1892
Brown, Robert, B.Sc., 45 Washington street. 1893
135 Brownlee, Jno., M.D., Glasgow Fever Hospital, Belvidere. 1902
Brownlie, John Douglas, M.B., Ch.B., L.D.S., 10 Brandon place. 1901
Brownlie, J. Rankin, L.D.S. (Eng.), 220 West George street. 1892
Bruce, Alex., Clyne House, Pollokshields. 1901
Bruce, David, M.A., LL.B., 141 West George street. 1897
140 Bruce, John, Inverallan, Helensburgh. 1902
Bryce, John, Assoc. M.Inst.C.E., Maxwell street, Partick. 1900
Bryden, Robert A., F.R.I.B.A., F.S.I., 147 Bath street. 1872
Buchan, David W., Fairy Knowe, Cambuslang. 1896
*a*Buchanan, Andrew, Dunfillan, Helensburgh. 1902
145 *a*Buchanan, A. W. G., Parkhill, Polmont, Stirlingshire. 1903
Buchanan, George Douglas, Silverrae, Giffnock. 1901
Buchanan, George S., 85 Candleriggs. 1845
Buchanan, Peter, 7 Garthland street. 1901

Buchanan, Robert Macneil, M.B., C.M., F.F.P.S.G., 2 Northbank terrace, Kelvinside. 1900

150 Buchanan, Walter, Clerkhill House, Dumbarton. 1901

*a*Buchanan, Wm. Enderley, Bearsden. 1886

Burnet, John James, A.R.S.A., F.R.I.B.A., 70 University avenue. 1892

Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864

*a*Burrell, Wm, 54 George square. 1900

155 Burton, William L., 6 Richmond crescent, Glasgow. 1899

Burr, Robert A., M.A., 26 Barnwell terrace, Govan. 1904

Caird, Robert, LL.D., F.R.S.E., 56 Esplanade, Greenock. 1898

Calder, Wm Ramsay, 102 Hope street. 1901

*a*Caldwell, George B., Scotia Leather Works, Boden street. 1892

160 Caldwell, James, 6 Newton place. 1900

Cameron, Sir Hector C., M.D., Professor of Clinical Surgery, University of Glasgow, 200 Bath street. 1873

*a*Campbell Arch., Springfield quay. 1895

*a*Campbell, J. A., LL.D., M.P., Stracathro, Brechin. 1848

Campbell, James Murdoch, 147 George street. 1901

165 Campbell, John, 49 St Andrew's drive, Pollokshields. 1901

*a*Campbell, John Ferguson, 2 Holborn terrace, N. Kelvinside. 1892

Campbell, John M., F.E.I.S., Kennedy St Public School, and 14 Royal crescent, Crosshill. 1900

Campbell, John MacNaught, C.E., F.Z.S., F.R.S.G.S, 6 Franklin terrace, Dumbarton road. 1883

Campbell, Malcolm, 18 Gordon street. 1894

170 Campbell, Joseph Dawson, 142 West George street. 1903

*a*Campbell, Thomas, Maryhill Iron works. 1894

Cant, James, Kilmeny, Ardrossan. 1901

Carlile, William W., Broomfield cottage, Largs, Ayrshire. 1897

Carmichael, Neil, M.D., C.M., F.F.P.S.G., Invercarmel, 23 Nithsdale drive, Pollokshields. 1873

175 Carswell, John, F.F.P.S.G., L.R.C.P.Ed., 5 Royal crescent, W. 1903

Carver, Thomas, A.B., B.Sc., D.Sc., C.E., 8 Windsor quad., Kelvinside. 1890

Cayzer, Herbert Robin, Ralston, Renfrewshire. 1901

*a*Cayzer, Sir Charles W., M.P., 109 Hope street. 1886

Chalmers, A. K., M.D., D.P.H. (Camb.), 7 Buckingham terrace. 1892

180 Chalmers, George, 13 Hamilton crescent, Partickhill. 1896

Chalmers, James, I.A., 93 Hope st. 1884

Chalmers, P. MacGregor, I.A., F.S.A.Scot., 95 Bath street. 1891

Chamen, W. A., Drumard, Partickhill road. 1898

Chisholm, James, 16 Knowe terrace, Pollokshields. 1899

185 Chisholm, John Oliver, surgeon, 16 Windsor terrace, St George's road. 1900

Chisholm, John, Airdrie. 1904

*a*Chisholm, Sir Samuel, Bart., LL.D., 20 Belhaven terrace. 1890

Christie, James Roberton, M.A., LL.B., 3 Gloucester place, Edinburgh. 1903

*a*Christie, Henry W., 46 West George street. 1892

190 Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868

Christie, Wm. E., M.A., 47 Millbrae road, Langside. 1903

*a*Christison, George, 13 Cambridge drive. 1897

Chrystal, W. J., F.I.C., F.C.S., Shawfield Works, Rutherglen. 1882

Clanachan, John, 4 Lloyd street, Dennistoun. 1900

195 Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870

Clark, John, 9 Wilton crescent. 1872

Clark, John, M.A., 2 Kelvingrove terrace. 1897

*a*Clarke, James Ferguson Wylie, M.A., F.R.C.S.Ed., 24 Buckingham terrace, Edinburgh. 1900

Cleghorn, Alexander, 10 Whittinghame drive, Kelvinside. 1904

200 *a*Cleland, John, M.D., LL.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 1884

*a*Coats, Archibald, Woodside, Paisley. 1900

Coats, John J., M.A., 27 Woodside place. 1900

*a*Cochran, Robert, 7 Crown circus, Dowanhill. 1877

Coghill, William C., 24 Douglas st. 1873

205 Colquhoun, Walter, M.A., M.B., C.M., 7 Stanley street, W. 1900

Colville, James, M.A., D.Sc., 14 Newton place. 1885

Colvin, Thomas, M.D., 6 Royal terrace, Crosshill. 1900

*a*Combe, James Russell, 10 Camphill avenue, Langside. 1895

*a*Connell, Charles Broadfoot, Scotstoun Shipbuilding Yard, Whiteinch. 1900

210*a*Connell, James G., 44 St Enoch's square. 1900
Connell, William, jun., Coldstream, Cathkin road, Langside. 1897
Connor, George Muir, M.B., C.M., 574 Gallowgate. 1900
Cook, William, 77 St Vincent street. 1900
Copland, Wm R., M.Inst.,C.E.,F.S.I., 146 West Regent street. 1876
215 Core, Wm, M.D., Stobhill Hospital, Springburn. 1891
Cormack, J. D., B.Sc., Prof. of Mechanical Engineering, University College, Gower street, London, W.C. 1898
Corrie, David, F.C.S., "Nobels," Polmont Station. 1902
Costigane, J. T. Stewart, Limekilns House, East Kilbride. 1889
Costigane, William, Clifton hall, Albert drive, Pollokshields. 1890
220 Coubrough, A. Sykes, Parklea, Blanefield, Strathblane. 1869
Coulson, W. Arthur, 47 King street, Mile-end. 1888
Couper, James, Craigforth House, Stirling. 1862
Couper, Sinclair, Moore Park Works, Helen street, Govan. 1896
Cowie, Archd., 20 Blythswood sq. 1900
225 Craig, T. A., C.A., 139 St Vincent street. 1886
*a*Crawford, R. C., 12 Derby crescent, Kelvinside. 1902
Cree, Thomas S., 21 Exchange square. 1869
Crichton, James, 201 Nithsdale road, Pollokshields. 1892
*a*Crookston, George B., 188 St Vincent street. 1900
230 Cross, Alexander, M.P., 14 Woodlands terrace. 1887
*a*Cruikshank, Robert Alexander, J.P., shipowner, Ardbeg, Kilmun. 1901
*a*Crum, Walter G., Dalnotter House, Old Kilpatrick. 1895
Crum, William G., Dalnotter House, Old Kilpatrick. 1896
Culbert, James, 12 Eildon Villas, Mount Florida. 1902
235*a*Cullen, Alexander, F. R. S. E., F.R.I.B.A., Millburn, Dalserf, by Netherburn. 1901
*a*Curphey, Wm Salvador, Borva, Lenzie. 1883
*a*Cuthbertson, Sir John N., LL.D., 29 Bath street. 1850

Dalrymple, James D. G., F.S.A., Meiklewood, Stirling. 1902
*a*Daly, James, 2 Prince's gardens. 1898
240*a*Dalziel, T. Kennedy, M.B., C.M., 196 Bath street. 1896
Dansken, A. B., 109 St. Vincent street. 1877
*a*Dansken, John, I.M.,F.S.I.,F.R.A.S., 241 West George street. 1876
Darling, William, 178 St Vincent street. 1901
Dennison, William, C.E., 175 Hope street. 1876
245 Dewar, David, 31 Arlington street. 1903
*a*Dick, George Handasyde, 30 Renfield street. 1887
Dick, Thomas, 166 St Vincent street. 1901
Dickie, John S., 30 Renfield street. 1900
*a*Dixon, A. Dow, 10 Montgomerie crescent, Kelvinside. 1873
250*a*Dixon, James S., Fairleigh, Bothwell. 1900
Dixon, Walter, Derwent, Kelvinside gardens. 1893
Dobbie, A. B., M.A., 24 West Cumberland street. 1885
*a*Dobbie, Robert, Beechmount, Larbert. 1900
Docherty, P. Alpine, L.R.C.P., L.R.C.S.Edin., etc., 526 Springburn road. 1900
255*a*Donald, James Addie, 12 Waterloo street. 1900
Donald, John, 23 Queen Margaret drive, N. Kelvinside. 1872
Donald, William, J. A., 16 Lilybank gardens. 1877
Dougall, Franc Gibb, 165 Canning street. 1875
Douglas, Campbell, I.A.,F.R.I.B.A., 266 St Vincent street. 1870
260 Douglas, William M., 155 North st. 1903
Downie, J. Walker, M.B., C.M., 4 Woodside crescent. 1901
Downie, Robert, jun., Carntyne Dyeworks, Parkhead. 1872
Downie, Thomas, Hydepark Foundry. 1886
*a*Dreghorn, David, Greenwood, Pollokshields. 1896
265*a*Duncan, Eben., M.D., C.M., F.F.P.S.G., Queen's Park house, Langside road, *Hon. Vice-President.* 1873
Duncan, Hugh, M.A., LL.B., 54 West Nile street. 1895
Duncan, J. A., Hopeville, Bridge of Allan. 1896
*a*Duncan, Robert, Whitefield Works, Govan. 1890
Dunlop, David John, Inch Works, Port-Glasgow, and 198 Bath street. 1900
270 Dunlop, John, F.E.I.S., headmaster, Parkhead Public School. 1900

Dunlop, John, M.D., 1 Somerset place. 1900
*a*Dunlop, Nathaniel, 25 Bothwell st. 1870
*a*Dunlop, Thomas, 70 Wellington street. 1902
Dunn, Hugh Shaw, Earlston Villa, Caprington, Kilmarnock. 1901
275 Dunn, Robert Hunter, 4 Crown terrace, Dowanhill. 1878
Duthie, Andrew Drummond, 2 Rothesay Gardens, Partickhill. 1902
Duthie, James, 190 West George street. 1901
Dyer, Henry, M.A., D.Sc., C.E., 8 Highburgh terrace, Dowanhill. 1883

*a*Edington, George Henry, M.D., M.R.C.S. (Eng.), F.F.P.S.G., 225 Bath street. 1896
280 Edmiston, John C., M.D., F.F.P.S.G., 24 Wilton gardens. 1901
*a*Edwards, John, 4 Great Western terrace, west. 1883
Elliot, Professor G. F. Scott, M.A., B.Sc., F.L.S., F.R.G.S., Fore house, Kilbarchan, Renfrewshire. 1896
Elliott, Joseph J., City Chambers. 1901
Erskine, Jas, M.A., M.B., L.F.P.S.G., 351 Bath street. 1886
285 Ewan, Thomas, M.Sc., Ph.D., 57 Montgomery street, Kirklee, Glasgow. 1901
Ewing, James C., 14 Woodlands road. 1902
*a*Ewing, Wm, *Vice President*, 45 Renfield street. 1883

*a*Faill, John, 7 Winton drive, Kelvinside. 1901
Fairweather, Wallace, C.E., 62 St. Vincent street. 1880
290 Falconer, Patrick, 13 Sutherland street, Hillhead. 1876
Falconer, Thos, 50 Kelvingrove street. 1880
*a*Farquhar, Jas T., 47 Hope street. 1901
Farquhar, Wm R., St Malo, Kilmalcolm. 1892
Farrelly, John, 25 Elmbank crescent. 1901
295 Fawsitt, Charles A., 9 Foremount terrace, Partick. 1879
*a*Fergus, Freeland, M.D., F.R.S.E., F.F.P.S.G., *Hon. Secy.*, 22 Blythswood sq. 1887
Fergus, James, 58 York street. 1901
*a*Fergus, Oswald, D.D.S,, L.D.S., 12 Clairmont gardens. 1896
Ferguson, Alexr., 106 W. Regent st. 1901
300 Ferguson, David, Glenholm, Port-Glasgow. 1901
Ferguson, Fergus, 20 Royal terrace, West. 1900
Ferguson, James, 58 Millbrae road, Langside. 1897
*a*Ferguson, John, M.A., LL.D., F.R.S.E., Professor of Chemistry, University of Glasgow, *Hon. Vice-President.* 1869
Ferguson, John Forbes, 166 St Vincent street. 1895
305 Fife, William, jr, Fairlie, Ayrshire. 1901
Findlay, Joseph, Clairmont, Winton drive, Kelvinside. 1873
Finlayson, James, M.D., 2 Woodside place. 1873
Fleming, Dr Robert H., 19 Newton street, Charing cross. 1901
*a*Fleming, E. Brown, Mambeg, Dumbartonshire. 1900
310 *a*Fleming, James, 136 Glebe street. 1880
*a*Fleming, John, 241 St Vincent st. 1900
Flower, Collingwood, Auchnacrioch, by Yoker, Renfrewshire. 1901
*a*Forrester, Henry, 105 West George street. 1900
Forrester, Robert, 142 West Nile st. 1901
315 Foster, W. A., St Catherines, Newlands road, Langside. 1899
Fotheringham, T. B., 52 Barrland street, Maxwell road. 1889
*a*Fowler, John, 2 Grantly gardens, Shawlands. 1880
Fraser, James, 53 Queen Mary avenue, Crosshill. 1901
Fraser, Melville, 31 St Vincent place. 1890
320 *a*Fraser, Thomas Smellie, F.S.I., 209 St Vincent street. 1900
*a*Fraser, Wm, F.S.I., 209 St Vincent street. 1900
Freebairn, J. B., M.A., Napiershall Public School. 1900
*a*French, Thomas, 1 Kelvinside ter. 1897
Frew, Alex., C.E., Assoc. M. Inst. C.E., 216 West George street 1876
325 *a*Frew, William, Ph.D., King's place, Perth, c/o 11 Hillhead street. 1898
Fryers, Arthur John, 22 Bath street, Largs. 1899
Fullarton, Professor Robert, M.A., M.B., F.F.P.S.G., 276 Bath st. 1903
*a*Fullerton, Robt., M.D., 24 Newton place. 1896
Fulton, James, The Glen, Paisley. 1897
330 Fulton, James, 11 Queen's crescent, W. 1902
Fulton, R. C., Montclair, Prestwick. 1890
Fyfe, Alexander, 38 Burnbank gardens. 1897
Fyfe, A. Peden, 135 St Vincent st. 1900
Fyfe, Henry B., 115 St Vincent street. 1892

335 *a*Gairdner, C. D., C.A., 115 St Vincent street. 1886
Galbraith, John Alexander, 28 Belhaven terrace. 1902
Galbraith, Peter, 122 Wellington st. 1889
Galbraith, Walter M., 7 Holyrood crescent. 1893
Galloway, T. Lindsay, C.E., 175 West George street. 1881
340 Galt, Professor Hugh, M.B., C.M., F.F.P.S.G., D.P.H.(Camb.), 14 Berkeley terrace, W. 1900
Gardiner, John, 18 Gibson street, Hillhead. 1901
Gardner, Daniel, 36 Jamaica street. 1869
Gardner, John, 146 Trongate. 1901
Gardner, John R., 33 Huntly gardens, Kelvinside. 1900
345 *a*Garrett, Geo., Dunbeth lodge, Coatbridge. 1901
*a*Garrow, James R., 6 Pollok road. 1890
*a*Garroway, John, 694 Duke st. 1875
Gemmill, James Fairlie, M.A., M.D., Lecturer in Embryology, University of Glasgow. 1901
Gemmill, William, 62 Bath street. 1903
350 Gibb, Robert, 28 St Vincent crescent. 1902
Gibson, Charles R., Lynton, Mansewood, by Pollokshaws. 1895
Gibson, William, 17 Wilton mansions. 1896
Gilfillan, Wm, 129 St Vincent st. 1881
*a*Gillies, William, 23 University gardens. 1901
355 Gillies, W. D., 17 Royal Exchange square. 1872
Glaister, John, M.D., F.F.P.S.G., D.P.H.(Camb.), F.R.S.E., F.C.S., &c., Professor of Forensic Medicine and Public Health, University of Glasgow, 3 Newton place, *Vice-President.* 1879
*a*Glaister, Joseph Newbigging, M.B., C.M., 5 Ronald street. 1900
*a*Glen, Lawrence, 165 St Vincent st. 1900
*a*Glen, Robert, Carlston, Kelvinside. 1901
360 Goldie, James, 52 St Enoch square. 1883
Goodwin, Robert, C.E., 3 Lynedoch street. 1875
Goold, James B., Bank of Scotland, Dennistoun. 1902
*a*Gordon, James, Stonebyres, 14 Aytoun road, Pollokshields. 1901
Gordon, John, M.D., C.M., 3 Strathallan terrace, Dowanhill. 1900
365 *a*Gourlay, Charles, B.Sc., A.R.I.B.A., Professor of Architecture, Glasgow Technical College, 30 Hamilton drive, Hillhead. 1900
Gourlay, Robert, LL.D., 5 Marlborough terrace. 1904
Gow, J. R., 12 Renfield street. 1898
Gow, Leonard, 45 Renfield street. 1889
Gow, Leonard, jun., 45 Renfield street 1884
370 Gow, Robert, 3 Victoria circus, Dowanhill gardens. 1860
Graham, John Hatt Noble, Larbert House, Stirlingshire. 1900
*a*Graham, Robert, 108 Eglinton street. 1888
*a*Graham, William, B.L., 198 West George street. 1885
*a*Graham, William, C.A., 6 Royal crescent, W. 1900
375 Graham, Wm Edward Auld, 7 Royal Bank place. 1900
Grant, Rev. James Bell, B.D., 113 Hill street, Garnethill, St. Stephen's Parish Church. 1903
Graves, John William, Hydropathic, Kilmalcolm. 1901
Gray, Albert A., M.D., 14 Newton terrace. 1903
Gray, Alexander Elmworth, Port-Glasgow. 1901
380 Gray, Andrew, 30 Bath street. 1889
Gray, Andrew, LL.D., F.R.S., Professor of Natural Philosophy in Glasgow University. 1899
Gray, James, M.D., 15 Newton ter. 1863
Green, George, J.P., 40 Balshagray avenue, Partick. 1900
Greer, Thomas Arthur, Fairfield works, Govan. 1901
385 Greig, James R., Ravenswood, Crosshill. 1897
Grier, R. P., 54 Newark drive, Pollokshields. 1901
Grove, John, jun., 199 St Vincent street. 1902
Gumprecht, John, 8 Lyndoch street. 1900
Gunn, John, B.L., 144 Bath street. 1901
390 Gunn, N. B., F.F.A., F.I.A., President of the Faculty of Actuaries in Scotland, 35 St Vincent place. 1900
Guthrie, David William, 124 Pitt street. 1900
Guthrie, John, 17 Whittinghame drive, Kelvinside. 1901

Halket, George, M.D., F.F.P.S.G., 4 Royal crescent, W. 1889
Hall, Colonel Peter Wishart, V.D., Regent cottage, Duntocher. 1901
395 *a*Hamilton, John, I.A., 212 St Vincent street. 1885
Hamilton, William, 70 Glassford street. 1902
Hanbidge, James E., 8 Balmoral crescent, Crosshill. 1897
Hannay, P. M., Bridge of Allan. 1898

Harington-Stuart, R. E. S. (Colonel), Torrance, East Kilbride, N.B. 1900
400 Harrington, John C., 14 Queen's Gate, Dowanhill. 1901
*a*Harrington, J. P., Broadfield, Port-Glasgow. 1900
Harris, F. W., 32 Kyle Park, Uddingston. 1900
Harrison, John, J.P., 7 Granby ter. 1900
Harrowes, Rev. William Henderson, M.A., 29 Ashton terrace. 1902
405*a*Hart, Robert, 8 Greenlaw Avenue, Paisley. 1902
Harvey, William Ure, Norman Hurst, Bearsden. 1896
Harvie, William, 8 Bothwell terrace, Hillhead. 1888
Hedderwick, Maxwell, 22 St Vincent place. 1892
*a*Henderson, A. P., 20 Newton place. 1880
410 Henderson, Francis, 47 Union street. 1901
Henderson, George G., M.A., D.Sc., F.I.C., F.C.S., Professor of Chemistry, Glasgow and West of Scotland Technical College, 204 George street. 1883
Henderson, John, Towerville, Helensburgh. 1890
*a*Henderson, Thomas, 1 Lancaster crescent, Kelvinside. 1900
Henderson, Thomas Beath, M.D., 25 Lansdowne crescent. 1899
415*a*Henderson, William, 15 Cadogan st. 1873
Hendry, Geo. Scott, 310 St. Vincent street. 1895
Henry, R. W., 10 Garthland street. 1875
Higgins, Henry, jun., 248 West George street. 1878
Hinshelwood, James, M.A., M.D., 26 Woodside place. 1896
420 Hinshelwood, Thomas, Kennyhill house, Dennistoun. 1903
Hodge, James R., C.A., 135 Buchanan street. 1900
Hodge, William, 27 Montgomerie drive, Kelvinside. 1878
Hogg, Robert, 163 Nithsdale road, Pollokshields. 1865
Holmes, Daniel T., B.A., Ingleholm, Bridge of Weir. 1898
425 Honeyman, P. S., 12 South Park terrace. 1900
Hood, Archibald J., M.A., 36 Bentinck street. 1901
*a*Hope, James, Dean house, Lenzie. 1898
Horne, Joseph, M.B., C.M., 5 Windsor street. 1900
*a*Houldsworth, J. H., Rozelle, Ayr. 1900
430*a*Houldsworth, Wm Thos, Clerk in Holy Orders, 1 Mansfield street, Portland place, London, W. 1901
Houstoun, Wm Henry, Hillcrest, Cambridge drive. 1895
Howat, William, 37 Elliot street. 1885
*a*Hunt, John, Milton of Campsie. 1881
Hunter, James, 89 Mitchell street. 1900
435 Hunter, Richard H., Glentyan, Kilbarchan, Renfrewshire. 1900
Hunter, Robert, 72 Waterloo street. 1901
Hunter, Walter K., M.D., 7 Woodside place. 1899
*a*Hunter, Wm S., 70 Robertson st. 1889
Hutchison, John C., 8 Lansdowne crescent. 1900
440 Hutchison, Joseph, Woodside, Netherburn, Lanarkshire. 1901
Hutton, James, C.A., 203 West George street. 1897
Hutton, W. K., M.A., M.B., Senior Demonstrator of Anatomy, The University. 1900
*a*Hyslop, William, of Bank, New Cumnock. 1901

Inglis, John, LL.D., Pointhouse Shipyard. 1895
445*a*Inglis, Malcolm, 48 St Andrew's square. 1900
Inglis, R. A., Culrain, Bothwell, 1889
Innes, Gilbert, 27 Hamilton drive, Hillhead. 1900
Inverclyde, Lord, The Right Hon., Castle Wemyss, Wemyss Bay. 1900
*a*Irons, Joseph Jones, Summerlea, Kilcreggan. 1902

450 Jack, William Robert, M.D., 43 Lansdowne crescent. 1899
*a*Jack, William, M.A., LL.D., Professor of Mathematics in the University of Glasgow. 1881
Jackson, Harold D., Westdel, Dowanhill. 1902
Jackson, Robert, 16 Dixon avenue, Crosshill. 1902
Jackson, Thomas, C.A., 24 George square. 1900
455 Jamieson, Andrew, F.R.S.E., M.Inst.C.E., M.Inst.E.E., etc., 16 Rosslyn terrace, Kelvinside. 1881
Jenkins, James Graham, Airedale, Cambuslang. 1901
Jenkins, Thomas, Woodlands, Crosshill. 1901
Johnston, Alex., M.D. (Glasgow), D.P.H. (Camb)., Ruchill Hospital. 1900
Johnston, David, 160 West George street. 1891
460 Johnston, Jas., 1005 Garngad road, Provanmill. 1903
Johnston, Michael, 19 Waterloo st. 1903

Johnston, William G., Anchor Chemical Works. 1901
Jubb, John, B.L., 190 West George street. 1902

Kay, Arthur, J.P., Tregortha, Winton drive. 1904
465 Kay, Cathcart, 77 St Vincent street. 1900
Kay, Thomas, M.B., C.M., 5 Rosebery terrace. 1899
Kean, James, 31 Scotia street, Garnethill. 1888
*a*Kelly, Alexander, 100 Hyde Park street. 1901
Kelly, Hugh, M.D., Catrine Bank, Shields road, Pollokshields. 1898
470 Kelly, J. H., J.P., Parkhead. 1900
Kelly, James K., M.D., F.F.P.S.G., Park villa, Queen Mary avenue, Crosshill. 1889
Kelly, John Davidson, M.A., Stanley house, Bridge-of-Allan. 1901
Kemp, Wm (Alexander, Fergusson, & Co., Ltd), Ruchill, Maryhill. 1898
*a*Kennedy, Alexander, Kenmill House, Bothwell. 1902
475 Kennedy, James, 33 Greendyke street. 1889
Kennedy, Bailie John, Airdrie. 1904
*a*Kennedy, Moses Hunter, 217 West George street. 1901
*a*Kennedy, William, Partick, 13 Victoria crescent, Dowanhill. 1900
*a*Ker, Charles, M.A., C.A., 115 St Vincent street. 1885
480*a*Ker, Wm, 1 Windsor terrace, Kelvinside, West. 1874
Kerr, Geo. Munro, 34 West George street. 1890
Kerr, John G., M.A., LL.D., 15 India street. 1878
Kerr, William, 260 West George street. 1902
Key, William, 109 Hope street. 1877
485 Kidston, Geo. J., Finlaystone, Langbank. 1900
*a*Kidston, William H., 81 Great Clyde street. 1900
*a*Kiep, Johannes N., Imperial German Consul, 128 St Vincent street. 1900
*a*King, Chas M., Antermony house, Milton of Campsie. 1900
King, Sir James, Bart, LL.D., of Campsie, 115 Wellington street. 1855
490 King, Ex-Bailie John, 17 Queen's crescent. 1895
King, John C., 21 Newton place. 1898
Kirk, Robert, M.D., Newton cottage, Partick. 1877
Kirkpatrick, Alexander B., 88 St Vincent street. 1885
Kirkwood, James, Carling lodge, Ibrox. 1890
495 Knight, James, M.A., D.Sc., F.C.S., F.G.S., F.E.I.S., The Shieling, Uddingston. 1893
Knight, John, M.D., D.P.H. (Camb.), 4 Linn terrace, Cathcart. 1900
*a*Knox, David J., 19 Renfield street. 1890
Knox, John, Finnieston School. 1900
*a*Knox, John, 13 Montgomerie quadrant, Kelvinside. 1902

500 Laird, John, Royal Exchange Sale Rooms. 1879
Lamb, David, 155 Hyndland road. 1896
Lamberton, Alex., 8 Adelphi ter. 1900
Lamberton, Andrew, Blairtummock, Easterhouse. 1904
Lamberton, Hugh Alexander, Lylestone, Pollokshields. 1901
505*a*Lamberton, Hugh, 8 Adelphi ter. 1900
Lambie, Robert, Strathview, Larkhall. 1901
Lamond, Robert, M.A., LL.B., 163 West George street. 1894
Lamont, Alexander, Kelvinhaugh Public School, 10 Ardgowan terrace, Sandyford. 1900
Lang, William, F.C.S., Crosspark, Partick. 1865
510 Lang, W. R., D.Sc., F.I.C., F.C.S., Professor of Chemistry in the University of Toronto, Canada. 1899
*a*Langlands, E. W., 113 West Regent street. 1902
*a*Lauder, James, F.R.S.L., Glasgow Athenæum. 1892
*a*Lauder, John, 46 Gordon street. 1894
Laughland, David, Linwood House, Linwood, Renfrewshire. 1901
515 Laurie, Malcolm, B.A., D.Sc., F.L.S., Professor of Zoology (St Mungo's College), Clunaline, Lenzie. 1901
Law, James H., Brandon House, Ibrox. 1901
Law, John, R. K., 20 Ashton gardens, Dowanhill. 1896
*a*Lawson, Thomas, Birchgrove, Pollokshields. 1901
Lee, William, M.A., F.E.I.S., teacher, 2 Tantallon terrace, Ibrox. 1901
520 Leipper, James, 12 Park drive, 1901
Whiteinch. 1902
*a*Lindsay, Archd M., M.A., 87 West Regent street. 1872
*a*Lindsay, John, Conylea, Westbourne gardens, Kelvinside, 1902
Lochhead, Dugald Ferguson, 45 Cecil street, Hillhead. 1902
Logan, James, Grammar School, Uddingston. 1902

525 Lothian, A. Veitch, M.A., B.Sc., F.R.S.E., Lecturer, 16 Clarence drive. 1891
Love, James Kerr, M.D., C.M., 173 Bath Street. 1888
Love, William, 28 Royal Exchange square. 1901
*a*Low, Isaac, 60 Weaver street. 1898
Lumsden, Harry, M.A., LL.B., 105 West George street. 1900
530 Lundholm, C. O., Nobel's Explosives Factory, Ardeer, Stevenston. 1890

M'Ara, Alexander, 65 Morrison street. 1888
Macara, James, 19 Waterloo street. 1901
Macara, Mudie, 1 Belmont street. 1901
M'Arly, Thomas, 29 West George street. 1897
535 MacArthur, J. G., 26 West Princes street. 1874
*a*M'Arthur, John S., 45 Renfield street. 1890
M'Ausland, William F., 51 Buchanan street. 1903
Macaulay, C. E. (Colonel), 1901
Macbean, Ed, F.R.G.S., F.R.S.L., 31 Athole gardens. 1901
540 M'Bryde, Peter, M.B., 18 Queen's crescent, W. 1900
*a*M'Callum, Hugh, M.A., Shields Road School. 1902
M'Callum, Robert, jun., 69 Union street. 1891
*a*M'Clelland, Andrew Simpson, C.A., 4 Crown gardens, Dowanhill. 1884
M'Conville, John, M.D., 14 Parkgrove terrace. 1870
545 M'Cosh, Andrew K., Cairnhill, Airdrie. 1901
*a*M'Cowan, David, jun., 6 Eton gardens, 1898
M'Cracken, James, 5 Bowmont terrace, Kelvinside. 1889
M'Crae, John, 7 Kirklee gardens, Kelvinside. 1876
M'Creath, James, M.E., 208 St Vincent street. 1874
550 M'Culloch, Hugh, 154 West Regent street. 1880
M'Donald, Alexander Beith, M.Inst. C.E., city engineer, City Chambers. 1901
MacDonald, Charles, 55 Lochleven road, Langside. 1902
*a*M'Donald, John, 72 Great Clyde st. 1896
Macdonald, John King, J.P., Whittingham drive, Kelvinside. 1900
555*a*Macdougall, Robert, F.S.A.A., F.S.I., 138 West Regent street. 1900
M'Elligott, John, 4 Victoria drive, Mount Florida. 1901
*a*M'Ewen, Robert, 11 Park terrace. 1900
*a*Macfarlane, Walter, 22 Park circus. 1885
M'Farlane, Wm, Edna Lodge, Rutherglen. 1888
560*a*M'Gilvray, R. A., 129 West Regent street. 1880
M'Gregor, A. N., M.D., 121 Douglas street. 1900
*a*Macgregor, R. D., 137 West George street. 1900
Machell, Thomas, 1 Burnbank ter. 1886
*a*Macindoe, Alex., 104 West George street. 1894
565 Macintyre, John, M.B., C.M., 179 Bath street. 1895
*a*M'Intyre, T. W., 21 Bothwell street. 1900
M'Intyre, Wm, F.E.I.S., Appin, Melrose avenue, Rutherglen. 1901
Mackay, R. C., 82 West Regent street. 1903
M'Kean, Francis, 235 Bath street. 1903
570*a*M'Kechnie, D., 14 Candleriggs. 1900
M'Kellar, John C., 224 St Vincent street. 1896
M'Kellar, J., 25 Kelvinside terrace. 1893
*a*M'Kendrick, John G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R C.P.E., Professor of Physiology in the University of Glasgow, 2 Buckingham terrace, *Hon. Vice-President*. 1877
M'Kendrick, J., Souttar, M.D., F.R.S.E., 2 Buckingham terrace. 1900
575 Mackenzie, John Alexander, M.B., C.M., 7 Sinclair drive, Langside. 1900
Mackenzie, Thomas Riach, 16 Robertson street. 1901
*a*M'Kenzie, W. D., 43 Howard street. 1875
M'Kie, John, M.B., C.M., 24 Hillside terrace. 1899
Mackillop, Fred. G., M.A., LL.B., 128 St Vincent street. 1901
580*a*Mackinlay, James Murray, The Lee, Merchiston, Edinburgh, 1886
*a*Mackinlay, J. T. C., 210 Nithsdale road, Pollokshields. 1900
*a*Mackinlay, R. W., 52 Aytoun road, Pollokshields. 1900
Mackintosh, Donald J., M.B., C.M., Western Infirmary, 1894
Mackinnon, William, C.A., 34 West George street. 1904
585 MacLachlan, Dugald, B.L., 30 Renfield street. 1901
Maclae, A. Crum, 192 St Vincent street. 1884

M'Laren, Robert, Royal Bank, Garscube cross. 1898
MacLaurin, Robert, 13 Claremont gardens, Milngavie. 1895
M'Lay, James, C.A., 94 Hope street. 1900
590 Maclay, W., Thornwood, Langside. 1893
M'Lean, Angus, B.Sc., C.E., Principal, Technical School, Paisley. 1897
Maclean, A. B., Craigpark Works, Dennistoun. 1899
M'Lean, Charles R., L.R.C.P.E., L.R.P.S.G., 12 Annfield place, Dennistoun. 1900
Maclean, Magnus, M.A., F.R.S.E., D.Sc., Professor of Electrical Engineering, Glasgow and West of Scotland Technical College, 51 Kersland terrace, Hillhead, *Vice-President*. 1885
595*a*MacLehose, James J., M.A., 61 St Vincent street. 1882
MacLellan, Lewis, 5 Bowmont gard. 1899
*a*Maclellan, Peter, Glasgow Rubber Works, Maryhill. 1900
*a*Maclellan, Wm. Walter, 3 Montague terrace, Kelvinside. 1900
*a*Macleod, A., 54 Tytherton road, Treefall park, London, N. 1893
600*a*Macleod, Frederick Larkins, 21 Huntly gardens, Hillhead. 1901
Macleod, the Rev. Donald, B.A., D.D., 1 Woodlands terrace, 1900
M'Michael, Thomas, M.A., B.Sc., 54 Windsor street. 1901
M'Millan, A. Lewis, M.D., C.M., 1 Rosebery terrace, Gt Western rd. 1897
M'Millan, Archibald, 5 Whittinghame gardens. 1899
605 M'Millan, Robert, Methlan park, Dumbarton. 1901
*a*Macnab, James, Lilyburn, Milton of Campsie, Stirlingshire. 1901
Macnair, Andrew Duncan, Benvue, Dowanhill gardens. 1901
Macnair, John, 136 Claythorn street, and 1 Morris place, Monteith row. 1900
Macnair, Matthew, 1 Morris place, Monteith row. 1901
610 Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
Macpherson, Duncan, Rosemount School. 1900
Macquaker, Thomas, 89 West Regent street. 1902
M'Raith, James N., 4 Queen's square, Strathbungo. 1900
M'Vail, D. C., M.B., Professor of Clinical Medicine, St Mungo's College, 3 St James' terrace, Hillhead. 1873
615*a*Macwhannell, Ninian, 58 West Regent street. 1898
M'Whirter, W., 9 Walworth terrace. 1901
Main, Robert B., Broomrigg, Dollar. 1885
Malloch, A. M., Firhill, Garscube road. 1896
*a*Mann, James, 4 University gardens. 1900
620*a*Mann, John, C.A., 142 St Vincent street, *Hon. Treasurer*. 1856
*a*Mann, John, jun., M.A., C.A., 142 St Vincent street 1885
Mann, Ludovic MacLellan, 142 St Vincent street. 1897
*a*Mann, Robert M., 3 Montgomerie crescent. 1900
Manwell, James, The Hut, 4 Albert drive, Pollokshields. 1876
625 Marks, Samuel, 145 Great Eastern road. 1884
Marr, John, J.P., Dunjarg, Bellahouston, Govan. 1900
Marr, Hamilton Clelland, M.D., Woodilee Asylum, Lenzie. 1899
Marshall, James, Woodcroft, Crow road, Partick. 1900
*a*Marshall, Robt., 97 Wellington street. 1900
630 Martin, Jas F., 63 Brunswick st. 1895
Martin, John, writer, 58 West Regent street. 1901
Martin, Robert, 8 Burnbank terrace, W. 1897
Martin, William, 63 Brunswick st. 1903
Marwick, Sir J. D., LL.D., F.R.S.E., 19 Woodside terrace. 1878
635 Mathie, George M., 15 Dunard road, Rutherglen. 1895
Mathieson, J. H., 6 Park circus place. 1896
*a*Mathieson, T. O., 6 Park circus pl. 1896
Mavor, Henry A., 47 King street, Mile-end. 1887
Mavor, Samuel, 37 Burnbank gard. 1890
640 Maxton, J., 27 Cedars road, Clapham Common, London, S.W. 1900
May, A. H., 15 Athole gardens. 1898
Mayer, John, Strathview, Cathkin road, Langside. 1860
Meares, H. P., 34 Ancaster drive, Jordanhill. 1902
Mechan, Arthur, Scotstoun Ironworks. 1876
645 Mechan, Henry, Scotstoun Iron Works, Scotstoun. 1879
Medley, Dudley J., Professor of History in Glasgow University, 6 University gardens. 1901
Menzies, William Crawford, City Improvement Trust, 22 King st. 1895
Metcalfe, John Ramsay, 19 Montgomery quadrant. 1901
Millar, James, 152 Parliamentary rd. 1870

650 Millar, Robert, 2 Rosslyn terrace, Kelvinside. 1903
*a*Miller, Alexander Wingate, 79 West Nile street. 1900
Miller Alexander, jun., Marghan, Broomhill, Partick. 1899
*a*Miller, Arch. Russell, Hillpark, Bothwell. 1884
*a*Miller, George, Surrey House, Victoria Embankment, London, W.C. 1881
655 Miller, G. J., Frankfield, Shettleston. 1888
Miller, Hugh, M.A., F.R.S.E., 2 Bogton Avenue, Cathcart. 1901
Miller, James, 5 Hanover street. 1900
*a*Miller, J. C., 40 West Nile street. 1900
Miller, John, M.D., 323 Springburn road. 1900
660*a*Miller, Thomas Hodgson, Westcroft, Cleveland Walk, Bath. 1901
*a*Miller, Thos P., Cambuslang Dye-works. 1864
*a*Mirrlees, William J., 45 Scotland street. 1889
Mitchell, Alexander Brown, Avon Bank house, Larkhall. 1901
*a*Mitchell, Alex. Moncrieff, 8 Kew terrace, Kelvinside. 1903
665 Mitchell. Andrew, C.A., The Glasgow District Subway Co., St Enoch square Station. 1896
*a*Mitchell, Andrew Acworth, 7 Huntly gardens. 1903
*a*Mitchell, George A., F.R.S.E., 5 West Regent street. 1883
Mitchell, Wm James, M.A., B.L., 48 West George street. 1897
*a*Moffatt, Alexander, 23 Abercromby place, Edinburgh. 1874
670 Mollison, James, 30 Balshagray aven., Partick. 1889
*a*Mond, Robert Ludwig, B.A. (Cantab.), F.R.S.E., 20 Avenue road, Regent's park, London, N.W. 1890
*a*Monro, T. K., M.A., M.D., F.F.P.S.G., Professor of Medicine in St Mungo's College, 10 Clairmont gardens. 1897
*a*Monteith, Robert, Greenbank, Dowanhill gardens. 1885
Moore, Alexander, C.A., 50 Montgomerie drive, Kelvinside. 1869
675 Moore, Alexander George, M.A., B.Sc., 13 Clairmont gardens. 1886
*a*Moore, Robert Thomas, 13 Claremont Gardens. 1904
Morrice, Jas A., 1 Prince's ter., Dowanhill. 1883
*a*Morton, George, Horslethill road, Kelvinside. 1902
Morton, James S., 54 St Vincent street. 1903
680 Motion, James Russell, 266 George street. 1887
Motion, Thomas Mason, 6 Melrose street, Great Western road. 1897
Muir, Alexander, 400 Eglinton street. 1883
*a*Muir, Allan, Ardmay, Newlands road, Langside. 1881
Muir, Matthew Greenlees, 12 Waterloo street. 1901
685 Muir, Robert, M.D., F.R.C.P.E., Professor of Pathology in Glasgow University, 16 Victoria crescent, Dowanhill. 1899
*a*Muirhead, Andrew Erskine, Cart Forge, Cathcart. 1873
Muirhead, James, 2 Bowmont gardens, Kelvinside. 1887
*a*Muirhead, Robert F., M.A., B.Sc., 24 Kersland street, Hillhead. 1879
Munro, Alexander, M.B., C.M., 569 Gallowgate. 1900
690 Munro, Daniel, F.S.I., 10 Doune terrace, Kelvinside. 1867
*a*Munro, Donald Mackay, 88 St Vincent street. 1901
Munro, J. M. M., M.Inst. E.E., M.Inst.C.E., F.R.S.E., 136 Bothwell street. 1896
Murdoch, George, 40 St Vincent place. 1894
Murdoch, John, 208 West George street. 1901
695*a*Murdoch, Robert, 91 Maxwell road. 1880
Murray, Charles Robert, Woodbank, Partickhill. 1902
*a*Murray, Daniel, 5 Wilton gardens. 1896
*a*Murray, David, LL.D., 169 West George street. 1876
Murray, James, 246 Whitehill street, Dennistoun. 1901
700 Murray, John Bruce, 24 George square. 1890

Napier, Alex., M.D., F.F.P.S.G., Rose Bank, Queen Mary avenue, Crosshill. 1886
Napier, James, M.A., F.R.S.E., The Drums, Old Kilpatrick. 1900
Napier, Robert T., 75 Bothwell street, Glasgow. 1899
*a*Neilson, George, LL.D., Pitlochie, 11 Annfield terrace, Partick, *Vice-President*. 1897
705*a*Neilson, James, 116 Bishop street, Port-Dundas. 1896
*a*Neilson, John, Mollance, Castle-Douglas. 1900
*a*Neilson, Walter, Ewenfield, Ayr. 1900

Nelson, Alex., 63 North Frederick street. 1880
*a*Nelson, John E., 26 Queen street. 1900
710 Nelson, Thos C., Craiglea, Dennistoun. 1900
Ness, Professor R. Barclay, M.A., M.B., 19 Woodside place. 1902
*a*Newlands, Joseph F., 105 West George street. 1883
Nicol, James Monro, 105 Cheapside street. 1901
Nicoll, James H., M.B., 4 Woodside place. 1897
715 Nisbet, Thomas, M.Inst.C.E., Master of Works, City Chambers. 1902
Nish, Robert, 9 Claremont terrace. 1897

Orr, George Smith, 58 Renfield st. 1901
Orr, John, 101 Wellington street. 1901
Orr, Robert, 79 West Nile street. 1890
720 *a*Osborne, Hugh, 4 Kew terrace, Glasgow. 1899
*a*Oswald, Dr Landel Rose, Glasgow Royal Asylum. 1902

Park, James, 51 Milburn street. 1877
*a*Park, Lieut.-Colonel James Smith, V.D., 61 Hamilton drive. 1900
Park, Robert, M.D., 40 Grant street. 1894
725 Parker, Edward H., 11 Strathmore gardens, Hillhead. 1897
Parker, George, 180 Hope street. 1902
*a*Parker John Dunlop, C.E., 146 West Regent street. 1889
Parker, James H., B.L., C.A., 89 West Regent street. 1900
*a*Parnie, William, 27 Union street. 1897
730 Parry, Robert Henry, F.R.C.S.E., 25 Blythswood square. 1900
*a*Paterson, Robert, C.A., J.P., 105 West George street. 1881
Paterson, Wm., M.B., C.M. (Edin.), 43 Millbrae Road, Langside. 1902
Paton, James, F.L.S., Glasgow Art Gallery and Museum, Kelvingrove. 1876
Patrick, Joseph, M.A., C.A., 203 West George street. 1893
735 Patrick, Joseph, of Alex. Kay & Co., Royal Exchange buildings. 1900
Patterson, T. L., F.C.S., Maybank, Finnart street, Greenock. 1873
Pearce, C. W. Bream, Nithsdale, Maitland avenue, Langside. 1903
Petrie, Alexander, I.A., 134 Wellington street. 1885
Petrie, John W., 4 Garrioch drive, Kelvinside, N. 1900
740 Pettigrew, Andrew H., Chesters, Bearsden. 1902
*a*Picken, David Kennedy, B.A., Ashburne, Partickhill. 1903
Pinkerton, Surgeon Major General, M.D., K.H.P., Queen's Park House, Langside. 1900
*a*Pirrie, Robert, 9 Buckingham ter. 1875
Playfair, David James, 7 Victoria crescent, Dowanhill. 1901
745 Pollock, A. Barr, M.B., C.M., 3 Belgrave terrace, Hillhead. 1897
*a*Pollock, R., M.B., C.M., F.F.P.S.G., Laurieston house, Pollokshields. 1883
Powell, James, Newlands School. 1900
Procter, Robert, Claremont, Alloa. 1901
*a*Provan, James, 92 West Nile st. 1868
750 Provand, A. D., M.P., 2 Whitehall court, London, S.W. 1888

Raalte, Jacques Van, Baltic Chambers, 50 Wellington street. 1884
Raleigh, Professor Walter, M.A., of Glasgow University, 2 South Park terrace. 1901
*a*Ralston, William Henry, 4 North Court, Royal Exchange. 1900
Ramsay, G. G., LL.D., Litt. D., Professor of Humanity in Glasgow University, 6 The College. 1900
755 Ramsay, William, 11 Wilton mansions, Kelvinside, 1899
Ramsey, Robert, 14 Park terrace. 1889
*a*Ramsey, Robert, jun., 14 Park terrace. 1898
Rankin, The Rev. W. M., B.D., clergyman, 8 Craigpark, Dennistoun. 1900
Rankine, Adam, Rolandseek, Bridge of Weir. 1901
760 Rankine, David, C.E., 238 West George street. 1875
Rattray, Rev. Alex., M.A., Parkhead Parish, 4 Westercraigs, Dennistoun. 1879
*a*Reid, Andrew Thomson, 10 Woodside terrace. 1900
Reid, David, 16 Cambridge street. 1887
*a*Reid, Hugh, Belmont, Springburn. 1880
765 Reid, James, 15 Montgomerie crescent. 1886
*a*Reid, Joseph, 32 Newark drive, Pollokshields. 1901
*a*Reid, Nicholas M'Whirter, 7 Oakley terrace, Dennistoun. 1901
Reid, Robert, C.A., 40 St Vincent pl. 1900
Reid, Thos, M.D., LL.D., 11 Elmbank street. 1869
770 Reid, William, M.A., 61 Grant st. 1881
*a*Reid, Walter M. N., 10 Woodside terrace. 1904
*a*Reid, William L., M.D., 7 Royal crescent, West. 1882

Renton, James Crawford, M.D., L.R.C.P. & S.Ed., 1 Woodside terrace. 1875
*a*Rennie, John, Wellcroft, Helensburgh. 1901
775*a*Renwick, Wm, Langgarth, Stirling. 1901
Rey, Hector, B.L., B.Sc., Margo villa, Buchanan drive, Rutherglen. 1889
Richmond, Thos, L.R.C.P.E., 22 Holyrood crescent. 1887
Rigg, R. A., 95 Buchanan street. 1900
Robb, George, carting superintendent, Caledonian Railway. 1901
780 Robb, William, F.R.C.V.S., 6 Canning place, Stirling road. 1900
*a*Roberton, William, 223 Sauchiehall street, Glasgow. 1899
*a*Robertson, Henry Tod, Meadowbank, Airdrie. 1901
Robertson, John, Woodside school, and Endcliffe, Langside, *Hon. Librarian.* 1860
Robertson, J. M'Gregor, M.A., M.B., C.M., 26 Buckingham ter., Hillhead. 1881
785 Robertson, Mure, M.E., 4 Clairmont gardens. 1897
*a*Robertson, Robert, B.Sc., M.Inst. C.E., M.I.E.E., etc., 154 West George street. 1900
Robertson, Robert H., Clyde bank, Rutherglen. 1888
Robertson, William, C.E., 121 St Vincent street. 1869
Robertson, Wm, 15 Gordon street. 1900
790 Robinson, Thomas, The Villas, Hurlet, Nitshill. 1901
Rodger, Anderson, Glenpark, Port-Glasgow. 1899
Roemmele, C. H., 34 Kelvinside gardens. 1900
*a*Rogers, John C., 204 Bath street. 1888
Rose, Alexander, Richmond house, Dowanhill. 1879
795 Rose, Hugh, 26 Eglinton drive. 1900
*a*Ross, John 9 Westbourne gardens. 1885
Ross, John, Munn, C.A., 117 Wellington street. 1894
Ross, Russell James, manager, Parkhead Steel Works, 8 Ashfield gardens, Jordanhill. 1901
*a*Rottenburg, Paul, LL.D,. 55 West Regent street. 1872
800 Rowan, James, 22 Woodside place. 1897
Rowan, John, M.B., F.F.P.S.G., 10 Woodside crescent. 1900
Rowan, W. G., 234 West George street, 1881
*a*Rowley, Thos, Campbell street, Govan. 1901
Runciman, Alex., 45 Renfield street. 1900
805 Russell, James, c/o Cluness, 25 Woodside quadrant. 1904
Russell, Robert, M.E., Coltness Iron Co., Ltd., Newmains, Lanarkshire. 1901

Salmon, W. Forrest, F.R.I.B.A., 53 Bothwell street. 1870
*a*Samuel, John Smith, F.R.S.E., J.P., secretary to the Lord Provost of Glasgow, City Chambers. 1901
Sandeman, B., Ferndean, Lenzie. 1900
810 Sandilands, Robert Douglas, 241 West George street. 1902
Sawers, William D., Assoc.I.C., Athole Garden place. 1894
Sayers, William Brooks, M.I.E.E., 189 St Vincent street. 1890
Scott, Alexander, M.D., 2 Newton place. 1900
Scott, Alex., 34 Lawrence street, Dowanhill. 1871
815*a*Scott, D. M'Laren, 2 Park quadrant. 1881
Scott, John, 249 West George street. 1892
Scott, Robert, I.M., 115 Wellington street. 1884
Scott, Robert, 8 Buchanan street. 1901
Scougal, Andrew E., M.A., 14 Kelvin Drive, Kelvinside, N. 1899
820 Seligmann, Hermann L., 30 Renfield street. 1850
Sellar, Charles, B.L., 65 Bath street. 1901
*a*Service, Edward, 92 St Vincent st. 1901
Service, R. Gibson, 14 Royal Exchange buildings. 1900
*a*Service, William, 1 Queen's gate, Dowanhill. 1900
825 Sexton, A. Humboldt, F.C.S., F.I.C., F.R.S.E., Professor of Metallurgy, Glasgow and West of Scotland Technical College, 204 George street. 1892
Shand, F. J., 4 Bowmont gardens, Kelvinside. 1903
*a*Shanks, J. B., 46 Gordon street. 1900
Shanks, John Cochrane, 103½ St Vincent street. 1899
*a*Shaw, A. M'Innes, Dunard, Sydenham, Dowanhill. 1900
830 Shaw, William, Ivy Lodge, Dullatur. 1900
*a*Shearer, Wm, 108 St Vincent street. 1901
*a*Sherriff, George, Carronvale, Larbert, Stirlingshire. 1900
Shields, Daniel, 104 West George street. 1900
Simons, Michael, 2 Kensington gate. 1880
835*a*Simpson, J. C., M.D., 9 Marlborough terrace, Kelvinside. 1896

Sloan, George, 53 Bothwell street. 1900
Sloan, Samuel, M.D., 5 Somerset place.
Smart, William, M.A., LL.D., Professor of Political Economy, University of Glasgow, Nunholm, Dowanhill. 1886
Smellie, George, I.M., 167 St Vincent street. 1880
840 Smellie, James, I.M., 112 Bath street. 1901
*a*Smith, Andrew, Miltonlea, Kilmalcolm. 1901
Smith, Colonel J. N , V.D., Dykebar house, Hawkhead, Paisley. 1900
Smith, D. Johnstone, C.A., 142 St Vincent street. 1888
*a*Smith, David Baird, LL.B., 205 St Vincent street. 1903
845 *a*Smith, Fred. J., 40 St Vincent place. 1901
Smith, George, 1 Annfield terrace, East Partick. 1901
Smith, Hugh C., 55 Bath street. 1861
*a*Smith, J. Guthrie, 205 St Vincent street. 1875
*a*Smith, James Murray, 11 Bute gardens. 1901
850 Smith, G. Comrie, 3 Seyton avenue, Langside. 1903
Smith, Patrick A., M.D., F.F.P.S.G., J.P., Dundrennan, 50 Queen Mary avenue, Crosshill. 1900
*a*Smith, Robert B., Bonnybridge, Stirlingshire. 1884
*a*Smith, W.B., 34 Buchanan street. 1895
*a*Smith, W. Robertson, 8 Windsor terrace, W. 1902
855 Snodgrass, J. F., Ashbourne, Winton drive, Kelvinside. 1900
Snodgrass, William, M.A., M.B., C.M., F.F.P.S.G., 11 Victoria cres., Dowanhill. 1890
*a*Somerville, Alex., B.Sc., F.L.S., 4 Bute mansions, Hillhead. 1888
Sorley, Robert, 93 St Vincent st. 1878
*a*Spencer, Charles L., Edgehill, Kelvinside. 1891
860 *a*Spencer, J. J., Edgehill, Kelvinside. 1895
Spens, John A., 169 W. George street. 1879
Steel, James, M.A., 502 St Vincent street. 1901
*a*Steel, William Strang, Philiphaugh, Selkirk. 1889
*a*Stephen, John, Domira, Partick 1880
865 Sterling, John Lockhart, 30 Ashton gardens, 1901
Steven, Henry, 20 Ingram street. 1900
Steven John, Eastvale place, Kelvinhaugh. 1875
*a*Stevenson, D. M., 12 Waterloo street. 1889
Stevenson, John G., 147 St Vincent street. 1903
870 Stevenson, J. V., Dunacre, Beech avenue, Bellahouston. 1902
Stevenson, Samuel, 4 Royal terrace, Crosshill. 1902
Stevenson, William, 13 Carlton place. 1888
Stewart, Allan Alfred, 180 Hope st. 1901
Stewart, David, Bridge of Allan. 1856
875 Stewart, John, 220 Parliamentary road. 1899
Stewart, Robert, Ellerslie, Partickhill. 1899
*a*Stewart, Robertson Buchanan, 146 Argyle street. 1901
Stewart, Walter, M.A., D.Sc., H.M. Inspector of Schools, 36 Kersland street. 1899
*a*Stobo, Thomas, Somerset house, Garelochhead. 1884
880 Stockdale, H. F., Clairinch, Milngavie. 1899
Stockman, Ralph, M.D., F.R.S.E., Professor of Materia Medica, The University of Glasgow. 1897
Stoddart, James Edward, Howden, Mid-Calder, N.B. 1872
Story, The Very Rev. R. H., D.D., Principal of the University of Glasgow. 1899
Strachan, George, Fairfield Works, Govan. 1900
885 Strachan, R. U., Sheriff-Substitute, 10 Crown circus. 1896
*a*Strain, James M., 15 Kingsborough gardens, W. 1900
*a*Strain, John, C.E., 154 W. George street. 1876
Strathie, David, C.A., 162 St Vincent street. 1895
*a*Sutherland, David, Balmaccara Hotel, Lochalsh. 1880
890 *a*Sutherland, John, Columba Hotel, Oban. 1880
Sutherland, J. R., C.E., 45 John street. 1884
Swan, Charles C., 15 Rose street, Garnethill. 1891
Tait, William, 43 Keir street, Pollokshields. 1902
Tatlock, John, F.I.C., 13 Parkgrove terrace, West, Sandyford. 1875
895 Tatlock, Robert R., F.R.S.E., F.I.C., F.C.S., 156 Bath street. 1868
Taylor, Benjamin, F.R.G.S., 10 Derby crescent, Kelvinside. 1872
Taylor, J. M., LL.D., late Dean of Faculty of Procurators, Northbank, Kelvinside. 1900
*a*Teacher, John H., M.B., C.M., 32 Kingsborough gardens, Dowanhill. 1898

Temple, Edwin, B.A.Cantab., Rector of Glasgow Academy. 1899
900 Templeton, James, 2 Claremont ter. 1900
Templeton, John Stewart, William street, Calton. 1900
Tennant, Sir Charles, Bart, 175 West George street. 1868
Tennent, Gavin P., M.D., 159 Bath street. 1875
Thom, R. Wilson, 8 Woodside ter. 1898
905 Thomas, Moses, M.D., 27 Buchanan Drive, Rutherglen. 1890
Thomson, R. S., M.D., D.Sc., Professor of Medicine (Anderson's Medical College), 17 Woodside terrace. 1901
Thomson, Gilbert, M.A., C.E., 164 Bath street. 1885
*a*Thomson, James, F.R.I.B.A., 88 Bath street. 1886
Todd, John Aiton, B.L., 190 West George street. 1897
910 Townsend, C. W., Crawford street, Port-Dundas. 1890
Trotter, Alexander M., M.R C.V.S., Moore street. 1902
Trotter, John, 40 Gordon street. 1899
*a*Tullis, James Thomson, Aytoun, Sydenham road, Dowanhill, 1883
*a*Tullis, John, John street, Bridgeton. 1900
915 Turnbull, Robert, 122 Wellington street. 1895
Turpie, John, 420 Sauchiehall street. 1896

Ure, William P., Balvaird, Helensburgh 1893

Vaughan, J., 7 Campside crescent, Langside. 1902
*a*Waddell, Robert Davidson, Rednock, Kelvinside, W. 1901
920 Walker, Adam, 26 Newton place. 1880
*a*Walker, Alexander, City Chambers. 1903
*a*Walker, Archibald, M.A.(Oxon.), F.I.C., F.C.S., 7 Crown terrace, Dowanhill. 1858
*a*Walker, Hugh, M.A., M.B., C.M., 52 Kilmarnock road, Shawlands. 1903
Walker, James A., 206 Bath street. 1898
925 Walker, John Allan, Art Master, Allanbank, Abbey Drive, Jordanhill. 1901
Walker, J. W. O., Highbury, Gravelly hill, Birmingham. 1896
*a*Walker, William H., Cardarroch House, Airdrie. 1900
Wallace, James Wilson, M.D , C.M., Cairnsmore, 67 St Andrew's drive, Pollokshields. 1900
Wallace, William, M.A., LL.D., barrister-at-law, 42 Athole gardens, Dowanhill. 1900
930*a*Wallace, Wm., M.A., M.B., C.M., 25 Newton place. 1888
*a*Wardlaw, Alex., The Clydesdale Bank, Ltd. 1900
Warren, John A., C.E., 94 Hope st. 1887
Watkinson, Wm H., Whit. Sch., M.Inst.,Mech.E., Professor of Steam and Steam Engines in the Glasgow and West of Scotland Technical College, 190 West Regent street. 1893
Watson, Archibald, 5 Westbourne ter. 1881
935 Watson, George Louden, 109 Hope street. 1901
Watson, Harold, 9 Holland place. 1901
Watson, James, 6 Kirklee road, Kelvinside, W. 1873
Watson, John, National Bank, Crosshill. 1900
Watson, Joseph, Chappell, Barrhead. 1882
940*a*Watson, J. Robertson, M.A., Professor of Chemistry, Anderson's College Medical School, Dumbarton road. 1891
*a*Watson, Thomas Lennox, I.A., F.R.I.B.A., 166 Bath street. 1876
Watson, William, M.D., Claremont, Langside. 1897
*a*Watson, William W., 5 Westbourne terrace. 1899
Watt, Alexander, 183 St Vincent st. 1900
945 Webster, H.Carvick, 48 Montgomerie drive. 1900
Webster, Rev. John M'Kessor, M.A., The Manse, Row, Dumbartonshire. 1901
*a*Weir, James, 72 St Andrew's drive, Pollokshields. 1902
*a*Weir, William, Shewalton, Dreghorn. 1901
Welsh, John M., Ph.D., F.E.I.S., F.R.G.S., 17 Brownlie street, Mount Florida. 1897
950 Welsh, Thomas M., 3 Prince's gardens, Dowanhill. 1883
White, J. Walls, M.D., Brunalb, Uddingston. 1900
White, John, Scotstoun Mills, Partick. 1897
Whitson, Arthur, 77 St Vincent st. 1901
*a*Whitson, Jas, M.D., F.F.P.S.G., Blairgowrie. 1882
955 Whyte, A. C., L.D.S., 42 Dundas street. 1892
Wield, John, 9 Barns street, Ayr. 1895
Williams, Alexander Malcolm, M.A., Church of Scotland Training College. 1903

Williamson, John, 65 West Regent street. 1881
Wilson, Alex., Hydepark Foundry, 54 Finnieston street. 1874
60*a* Wilson, David, M.A., D.Sc., F.C.S., Carbeth, Killearn. 1898
Wilson, Thomas F., 163 Hope st. 1901
Wilson, Thomas, 57 Cochrane street. 1902
Wilson, Walter Stuart, 4 St John's terrace. 1901
Wilson, Wm, F.E.I.S., School-house, Pavenham, Bedford. 1889
65 Wingate, Arthur, Broomcraig, Largs. 1882
Wingate, Walter E., 4 Bowmont ter. 1880
Wood, Adam, Portland villa, Troon. 1901
Wood, James, Dunard Street Public School, 2 Cresswell terr., Uddingston. 1900
Wood, James, M.A., Glasgow Academy. 1885
70*a* Wood, William James, 266 George st. 1893
Woodrow, Alexander, 75 Glassford street. 1900
Woodrow, Alexander Norie, 75 Glassford street. 1900
a Workman, Chas, M.D., F.F.P., & S.G., Professor of Pathology, St Mungo's College, 5 Woodside ter. 1898
Wright, Robert Patrick, Professor of Agriculture, West of Scotland Agricultural College, 6 Blythswood square. 1895
975 Wylie, William A., 13 Woodside ter. 1901
Wyper, James, Nithsdale Lodge, Pollokshields. 1900
Yellowlees, D., M.D., LL.D., 6 Albert gate. 1881
Young, David, M.D., Linton Villa, Parkhead. 1900
Young, Frank W., H.M. Inspector of Schools, 32 Buckingham ter. 1902
980*a* Young, James, jun., Caerleon, Bearsden. 1900
a Young, John E., 24 Belhaven ter, Kelvinside. 1900
Young, John, 8 Athole gardens, Hillhead. 1900
Young, John, 42 Bath street. 1900
Young, John, 2 Montague terrace, Kelvinside. 1885
985 Young, John, 88 Renfield street. 1881
a Young, John, jun., M.A., B.Sc., 61 Clyde street, Anderson. 1887
Young, John Ross, 65 Bath street. 1903
Yuill, John Weir, Glenmillhouse, Campsie Glen. 1901

APPENDIX.

Memorandum of Association.

1. The name* of the Association is "THE PHILOSOPHICAL SOCIETY OF GLASGOW."

2. The Registered Office of the Association shall be situate in Scotland.

3. The objects for which the Association is established are:—

(1) To absorb and continue the Association which has existed in Glasgow since 1802 under the name of "The Philosophical Society of Glasgow."

(2) To aid the study, advancement, and development of the Physical, Natural, Mental, and Moral Sciences, and the Arts of Design, with their applications, and the diffusion of scientific knowledge.

(3) The doing all such other lawful things as are incidental or conducive to the attainment of the above objects.

4. From time to time to purchase and hold heritable property for the Society and to sell the same.

5. To construct, alter, and maintain any buildings necessary or convenient for the purposes of the Society.

6 To invest the moneys of the Society not immediately required, upon such securities as may from time to time be determined.

7. To borrow money to such an extent, and upon such security, as may from time to time be determined by special resolution.

8. The income and property of the Association, whencesoever derived, shall be applied solely towards the promotion of the objects of the Association, as set forth in this Memorandum of Association; and no portion thereof shall be paid or transferred directly or indirectly by way of dividend or bonus, or otherwise,

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* By command of His Majesty, King Edward VII., (dated 27th March, 1901), the name is now "THE ROYAL PHILOSOPHICAL SOCIETY OF GLASGOW."

howsoever, by way of profit, to the persons who at any time are or have been members of the Association, or to any of them, or to any person claiming through any of them; provided that nothing herein shall prevent the payment in good faith of remuneration to any officers or servants of the Association, or to any member of the Association or other person, in return for any services actually rendered to the Association.

9. The eighth paragraph of this Memorandum is a condition on which a licence is granted by the Board of Trade to the Association, in pursuance of Section 23 of the Companies' Act, 1867. For the purpose of preventing any evasion of the terms of the said eighth paragraph, the Board of Trade may from time to time, on the application of any member of the Association, impose further conditions, which shall be duly observed by the Association.

10. If the Association act in contravention of the eighth paragraph of this Memorandum, or of any such further conditions, the liability of every member of Council of the Association shall be unlimited, and the liability of every member of the Society who has received any such dividend, bonus, or other profit as aforesaid, shall likewise be unlimited.

11. Honorary Members and Corresponding Members shall not pay any entrance fee or annual subscription, and neither they nor Associates of Sections shall be liable to contribute anything to the assets of the Association, in the event of the same being wound up.

12. Every Ordinary Member of the Association undertakes to contribute to the assets of the Association, in the event of the same being wound up during the time that he is a member, or within one year afterwards, for payment of the debts and liabilities of the Association contracted before the time at which he ceases to be a member, and of the costs, charges, and expenses of winding up the same, and for the adjustment of the rights of the contributories amongst themselves, such amount as may be required not exceeding Five Shillings, or in case of his liability becoming unlimited, such other amount as may be required in pursuance of the preceding paragraph, number ten, of this Memorandum.

13. If upon the winding up or dissolution of the Association there remains, after the satisfaction of all its debts and liabilities,

any property whatsoever, the same shall not be paid to or distributed among the members of the Association, but shall be given or transferred to some other institution or institutions, having objects similar to the objects of the Association, to be determined by the members of the Association at or before the time of dissolution, or in default thereof by such Judge of the Court of Session as may have or acquire jurisdiction in the matter.

We, the several persons whose names and addresses are subscribed, are desirous of being formed into an Association in pursuance of this Memorandum of Association.

NAMES, ADDRESSES, AND DESCRIPTIONS OF SUBSCRIBERS.

ANDREW FERGUS, M.D., President, 3 Elmbank Crescent, Glasgow.

WILLIAM WALLACE, Ph.D., Vice-President, 138 Bath Street, Glasgow.

ANDREW BUCHANAN, M.D., Vice-President, 4 Athole Place, Glasgow.

HENRY MUIRHEAD, M.D., V.P., Bushy Hill, Cambuslang.

JOHN ROBERTSON, Teacher, 10 Valeview Terrace, Cathcart.

JNO. MANN, Chartered Accountant, 83 West Regent Street, Glasgow.

EDWARD MAXWELL DIXON, Head Master, Glen's School, Glasgow.

ARCHIBALD ROBERTSON, Merchant, 33 Granville Street, Glasgow.

WILLIAM RAE WILSON SMITH, Yarn Merchant, 6 South Hanover Street, Glasgow.

Dated the 16th day of April, 1879.

THOMAS NAPIER, Library Keeper,
276 Sauchiehall Street, Glasgow,
Witness to the above signatures.

Articles of Association

OF THE

ROYAL PHILOSOPHICAL SOCIETY OF GLASGOW.

THE Regulations of Table A in the first Schedule to "The Companies' Act, 1862," shall not apply to the Association, but in lieu thereof, the following shall be the regulations of the Association:—

I.

For the purposes of registration the number of the Ordinary Members of the Association is declared not to exceed fifteen hundred, but the number may be increased from time to time by special resolution.

II.

These Articles shall be construed with reference to the provisions of the Companies Acts, 1862 to 1900, and terms used in these Articles shall be taken as having the same respective meanings as they have when used in those Acts.

III.

The Society is established for the purposes expressed in the Memorandum of Association.

IV.

MEMBERS.

1. The Society shall consist of three classes of Members,—Ordinary, Corresponding, and Honorary.

2. Ordinary Members shall be such persons as are duly elected according to the Articles of Association.

3. Corresponding Members shall be persons not resident in Glasgow, nor within twenty miles thereof, who have rendered valuable service to the Society, or from whom such service may be expected.

4. Honorary Members shall be persons who have contributed in an eminent degree to the advancement of the Sciences or the Arts.

V.

ORDINARY MEMBERS.

1. Candidates shall be proposed in writing by three Members; intimation of such proposals shall be given to the Society with the Circular calling the next ordinary meeting, at which they shall be balloted for, and shall be elected if more than *four-fifths* of the votes are favourable. The Secretary shall inform Members, by letter, of their election. Upon admission, every Member shall pay One Guinea as Entry-money, and One Guinea in addition as the first year's Annual Subscription; if he fail to comply with the terms of this Article within two months, his election shall be void.

2. Upon admission, each Member shall sign his name to the following Declaration, in a book kept for the purpose :—

DECLARATION.—"*I hereby bind myself to observe and obey the Laws of the* ROYAL PHILOSOPHICAL SOCIETY OF GLASGOW.

3. The Annual Subscription to the Society shall be One Guinea, due on the first of November. Members whose Subscriptions are in arrear shall not have the power to vote on any question, nor to use the Library, nor be entitled to receive the printed *Proceedings* of the Society.

4. Members shall be held liable for their Annual Subscriptions until they have given to the Secretary written notice of their resignation.

5. It shall be in the power of the Council to reinstate, without payment of any Entry money, Members who may have resigned Membership, and subsequently make application in writing to the Secretary for readmission.

6. Members who have paid their Entry-money may compound for their Annual Subscriptions by a single payment of Ten Guineas up till 1st January, 1905, after which the compounding subscription shall be Twelve Guineas.

VI.

CORRESPONDING MEMBERS.

Corresponding Members shall be recommended by a majority of the whole Council, and shall be balloted for in the same manner as Ordinary Members. They shall be liable to no payments, and shall each be entitled to receive a copy of the annual issue of the *Proceedings* of the Society.

VII.

HONORARY MEMBERS.

1. The number of Honorary Members shall not at any time exceed twenty; and not more than three shall be elected in any one year.

2. Honorary Members shall be recommended by a majority of the whole Council and shall be balloted for in the same manner as Ordinary Members. They shall be liable to no payments, and shall each be entitled to receive a copy of the annual issue of the *Proceedings* of the Society.

VIII.

If any Member is considered by the Council to have been guilty of misconduct such as to make necessary, or advisable, in the opinion of the Council, his removal from the Membership, the Council may, by not less than a two-thirds majority of the whole Council, resolve that such Member be requested to resign; and if, within ten days after intimation, the request be not complied with, the name of such Member shall, by order of the Council, be erased from the Roll, and he shall thereupon forfeit all the privileges of Membership. In all such cases, however, there shall be, when demanded by the Member, an appeal to a meeting of the Society.

IX.

CONSTITUTION OF THE COUNCIL.

1. The Council of the Society shall consist of the President, three Vice-Presidents, the Hon. Vice-Presidents, the Hon. Librarian, the Hon. Treasurer, the Secretary or Secretaries, the Presidents of Sections, *ex-officio* if otherwise eligible, and twelve Ordinary Members of Council, elected as hereinafter prescribed.

2. Members of the Society alone shall be eligible to a seat in the Council.

3. The Hon-Librarian, the Hon. Treasurer, and the Secretary or Secretaries shall each be appointed for one year, but each may be re-elected annually.

4. Other appointments to the Council shall be for a period not longer than three consecutive years, except in the case of Hon.

Vice-Presidents, (X, 2 and 3); and, subject to IX, 3, every retiring office-bearer shall be ineligible both to the office last held and to the Ordinary Membership of Council until the lapse of one year from the date of his retiral.

X.

PRESIDENT AND VICE-PRESIDENTS.

1. The President shall take the Chair at all meetings of the Society, or of its Council, at which he is present. In absence of the President, one of the Vice-Presidents shall take the Chair; when the President and Vice-Presidents are absent, any Member may be voted into the Chair. The President shall be a member *ex officio* of all the Standing Committees.

2. Presidents on retiring from Office shall be Honorary Vice-Presidents so long as they continue Members of the Society.

3. Any member who has for a period of not less than seven full years served the Society as Honorary Librarian, Honorary Treasurer, or Honorary Secretary may, on retiral from such office, be elected by the Council to the office of Honorary Vice-President.

XI.

LIBRARIAN.

The Hon. Librarian shall have charge of the books belonging to the Society, and shall keep a catalogue of them, and a register of their circulation among the Members. He shall purchase books only on the authority of the Council, or of a Library Committee appointed by the Council. He shall levy the fines incurred by breach of the Library Regulations, and pay over the same to the Treasurer one week before the annual accounts are made up. The Hon. Librarian shall have the assistance of a Sub-Librarian, duly appointed by the Council. The Hon. Librarian shall present to the Annual General Meeting a list of the additions made to the Library during the past year. The list shall be printed in the *Proceedings* annually.

XII.

THE LIBRARY.

I. Bye-laws for the regulation of the Library shall be made from time to time, which may be altered or repealed by resolution of any meeting of the Society.

II. The following shall, until altered as aforesaid, be the

Regulations for the Management of the Library.

1. The Books may be exchanged each lawful day, at such hours as the Council may from time to time determine.

2. Books shall not be taken from the Library until the borrower sends a written order, or signs his name for them against the entry in the Register of Books in circulation.

3. No reader shall be allowed more than one volume at a time of books that have been less than three months in the Library, or three volumes at a time of books that have been more than three months in the Library.

4. The time allowed for retaining the books, and the fines for non-return when borrowed shall be as follows:—

AFTER ADDITION.	TIME ALLOWED.	FINE IF KEPT LONGER.
First Three Months,	One Week,	One Penny per volume per Day.
After the Third Month,	Two Weeks,	Twopence per volume per Week.

5. The fines shall be paid to the Hon. Librarian or his substitute.

6. If any Member retains a volume beyond the times above specified, the Hon. Librarian or Sub-Librarian shall, in writing, require him to return it immediately; and if he does not comply, within a time considered reasonable or sufficient by the Council, the Society may replace it, charging him not only with the price, but also with the fines due up to the time of replacement for not returning it. If any book is damaged when returned the Society may replace it by a new copy at the borrower's expense. If the volume belongs to a set of books, the whole set must be so replaced, provided the volume wanting cannot be got apart.

7. If a reader who has incurred fines does not pay them, his right to borrow books from the Library shall be suspended during non-payment.

8. None but Members of the Society shall be entitled to borrow the books belonging to the Library.

9. Members engaged in drawing up papers to be read before the Society or any of its sections may have an extra number of volumes, and be allowed to retain them for a longer time, upon producing an order to that effect from the Secretary of the Society.

10. Rare and valuable books shall be divided into two classes; one not to be given out, and the other to be given out only on special application in writing to the Hon. Librarian.

11. All books shall be called in, and returned by the borrowers, for inspection one week before the Annual Meeting. The names of Members failing to comply with this Rule shall be exhibited on the Notice Board.

12. Any contingency not provided for in these Regulations shall be submitted to the Council, and their decision shall be final and binding on all concerned.

XIII.

TREASURER.

The Hon. Treasurer shall have in charge the Funds of the Society, and shall receive either personally, or by his substitute, or by a guaranteed Collector duly appointed by the Council, all payments due to the Society. Whenever the sum in his hands amounts to Fifty Pounds, he shall deposit it in one of the Glasgow Banks, in name of the President and himself conjointly. He shall pay such sums as may be ordered by the Council, and shall keep an account of all his intromissions in the Society's General Cash-Book, which account shall be balanced annually, on the 30th September, and be submitted to the Annual General Meeting, having been previously examined, with the Vouchers, by two Auditors (who shall not be Members of the Council) appointed by the Society at the last Regular Meeting in April. He shall also keep a Register of the Names of the Members of the Society, which shall be presented at the Annual General Meeting, together with an Inventory of all the Property (except the Library books) possessed by the Society.

XIV.

SECRETARY.

1. The Secretary shall record the Minutes in books kept for the purpose. He shall also conduct the Society's general correspondence, act as Secretary to the Council, and edit the *Proceedings*, subject to the approval of the Council. He shall be under the control of the Council, and receive such a Salary as the Council shall determine. He shall be a Member *ex officio* of all Committees of Council.

2. A Secretary in receipt of a salary from the Society, may take part in the deliberations and discussions at meetings of the Council, but shall not be entitled to vote upon any question there.

3. The offices of Treasurer and Secretary, respectively, may be held jointly by two persons, or may be conjoined. In the case of a joint appointment one of the holders of the office may be honorary and the other acting.

XV.

MEETINGS OF THE SOCIETY.

1. The REGULAR MEETINGS of the Society shall be held on alternate WEDNESDAY evenings, during the Session, from the beginning of November till the end of April, but the first Meeting in January of each year shall not be held earlier than the eleventh of the month. Extra Meetings of the Society may also be held.

2. The Secretary shall announce these Meetings by Circular addressed to all Members of the Society residing in the United Kingdom. The Circular shall contain a copy of the Minute of the previous Meeting, notices of motion, and other business to be brought before the Meeting announced.

3. Twenty Members shall constitute a quorum for ordinary business, but for the suspension of the Standing Orders the quorum shall be thirty.

4. Unless when otherwise arranged, the Chair shall be taken at eight o'clock, and the business shall proceed as follows :—

(1) The Minute of the previous Meeting shall be submitted.
(2) Admission of New Members.
(3) Papers to be read.
(4) Announcement of Ballot for New Members.
(5) Motions and General Business to be disposed of, commencing at 9.40 p.m., or as near that time as convenient.

5. To all Regular and Extra Meetings of the Society Members shall have, unless when otherwise determined by the Council, the right of introducing friends. Strangers, however, must retire if requested to do so by the Chairman.

6. SPECIAL MEETINGS may be called by the Council when they consider it necessary or proper ; and must be called by them on receipt of a requisition from ten Members specifying the business to be brought before such Meeting. Twenty Members

shall constitute a quorum should the Meeting be held during the Session, and thirty should it be held during the recess.

7. A BUSINESS MEETING of the Society shall be held annually on the third WEDNESDAY in November, or as near that day as may be convenient, due intimation of which meeting shall be communicated by the Secretary to all Members of the Society resident in the United Kingdom.

8. At this Meeting—

(1) The Council shall report on the state of the Society.
(2) The Treasurer shall exhibit an audited Statement of the Funds of the Society.
(3) The Librarian shall report on the state of the Library.
(4) Reports from the Councils of Sections shall be presented.
(5) Reports from the Society's Representatives on the Boards of other Bodies shall be presented.

9. At the last Regular Meeting in April the Society shall proceed to the filling up of vacancies in the Council, and the appointing of Auditors, in the following order:—

(1) Election of President (if it be part of the business).
(2) Election of Vice-Presidents.
(3) Election of Librarian.
(4) Election of Treasurer.
(5) Election of Secretary.
(6) Election of Members of Council other than the preceding Office-bearers.
(7) Appointment of Auditors.

10. For all the above vacancies the Council shall make nominations, and these shall be intimated on the billet calling the last meeting in March, at which, or the next regular meeting, additional nominations for any office may be made by any three Members of the Society. All nominations, with the names of the proposers appended, shall be printed in a ballot paper which shall be issued with the billet calling the last regular meeting in April.

XVI.

MOTIONS AND VOTING.

1. Votes for the Election of Office-bearers and the admission of Members shall be given by ballot; all other votes *vivâ voce.*

2. Any motion shall be carried by a simple majority of votes, excepting (*a*) for the admission of Members, when one-fifth of

the votes tendered shall exclude; and (*b*) for the suspension of the Standing Orders.

3. A motion for the suspension of the Standing Orders on being seconded, shall be put without debate, and shall not be carried by less than a two-thirds majority of votes.

4. No motion shall be entertained unless notice of it has been given at a previous Meeting, except a motion for the Suspension of the Standing Orders.

5. No motion shall be entertained which has been discussed and negatived at a Meeting of the Society during the same session.

6. Corresponding Members and Honorary Members shall not be entitled to vote at any Meeting of the Society.

7. Each Ordinary Member shall have one vote.

8. All votes shall be given personally.

9. In case of an equality of votes, the Chairman shall have a casting vote in addition to his deliberative vote.

10. No Member whose annual subscription is more than six months in arrear shall be entitled to vote at any Meeting of the Society.

11. All questions of Order not provided for in these articles shall be dealt with at the discretion of the Chairman.

XVII.

SECTIONS.

1. The Society may comprise Sections devoted to the study of any branch of Art or Science such as :—

The Architectural Section,
The Geographical and Ethnological Section,
The Mathematical and Physical Section,
The Economic Science Section,
The Historical and Philological Section,
The Sanitary and Social Economy Section,

always provided that the Constitution of any Section be subject to the approval of the Society.

2. The Society may, on the recommendation of the Council, constitute, reconstitute or discontinue any Section.

3. Each Section may meet separately, and read and discuss papers and otherwise transact business in accordance with the objects of the Section. It shall not be competent for any Section to take

public action by memorial, deputation, or otherwise, without the sanction of the Society. Each Section may have Associates, for each of whom the Section shall pay to the Treasurer of the Society Five Shillings annually; but the Members of the Society, being, *ipso facto*, Members of all the Sections, no sectional payment shall be made in respect to them. Associates shall not be entitled to the privileges of the Society, but may consult the books in the Library.

4. The Society shall not be responsible for the outlays of any Section, unless such outlays have been authorised by the Council.

5. Copies of separate papers printed for the *Proceedings* may be obtained by Associates at cost price, on timeous application being made to the Editor of the *Proceedings*.

6. The publications of the Society may be issued to Associates of Sections, or to the public, at such price or prices as the Council may from time to time determine.

7. The Minute Books and property of every Section shall be the property of the Society.

XVIII.

"Proceedings" of the Society.

The *Proceedings* of the Society shall be published annually. The *Proceedings* shall consist of a selection from the Papers which have been read at the Meetings of the Society and its Sections, or of abstracts of these Papers—such selection to be made by the Council. The author of a Paper published by the Society shall receive thirty copies of the same free of expense. A limited number of copies of the Papers to be included in the *Proceedings* shall be issued separately during the Session and sent to Members who make written application for one or more of them to the Editor—such application to have reference only to the Papers of the session then current. The Council shall select the Papers to be read before the Society.

XIX.

Functions of the Council.

1. The affairs of the Society shall be managed by the Council.

2. Ordinary Meetings of Council shall be called by Circular, intimating the business to be brought forward. Extraordinary

Meetings of the Council may be called by the President at his own discretion or shall be called, upon a requisition presented to him (or, in his absence, to one of the Vice-Presidents), signed by five Members of Council. At a Meeting of Council, five shall constitute a quorum. The Secretary shall record the proceedings in a Minute-Book.

3. A list of the Members of all Standing Committees of Council shall be printed in the first Circular after their appointment.

4. The Council shall administer the Funds of the Society. They shall defray all charges which they consider necessary and proper for the ordinary work of the Society. It shall not be competent for the Council to undertake extraordinary expenditure without the consent of the Society, obtained at two successive Meetings.

5. Appointments to salaried offices in the Society shall be made by the Council and duly announced to the Society. Any such appointment, however, may be annulled by motion duly made and carried at any Meeting of the Society held within one calendar month from the date on which the appointment was so announced.

6. The Council shall have power to make Bye-laws, which shall be subject to confirmation by the Society, and to appoint such Committees as they may from time to time deem necessary.

7. Vacancies in the Council arising during the currency of a session may be filled up, *ad interim*, by the Council, if they deem it expedient to do so, and the Society shall at the next ensuing annual election fill each such vacancy for the remainder of the term of the original member's appointment. A Member so appointed by the Council shall retire at the next ensuing annual election, but shall be eligible for immediate re-election, provided his period of service has not extended to more than twenty-one calendar months.

XX.

The foregoing Articles of Association shall supersede and take the place of all former Articles of Association of the Society, and shall come into operation on the first of January, 1905.

With reference to the foregoing Memorandum and Articles of Association the following Special Resolutions of the Philosophical Society of Glasgow were passed 6th April, and confirmed 27th April, 1904:—

SPECIAL RESOLUTIONS.

(1) That His Majesty The King having expressed his approval of the word "Royal" being prefixed to the name of the Society, resolved that the name of the Society be changed to "THE ROYAL PHILOSOPHICAL SOCIETY OF GLASGOW."

(2) That the Regulations contained in the printed document submitted to the Meeting, and, for the purpose of identification, subscribed by the Chairman thereof, be, and the same are hereby approved; and that such Regulations be, and they are hereby adopted as the Regulations of the Society; and that the same shall come into operation on the first day of January, 1905, to the exclusion of all the existing Regulations thereof.

FREELAND FERGUS, *Hon. Secy.*
PETER BENNETT, *Acting Secy.*

INDEX.

Absolute units, system of, 27 ; Electrical, 30.
Abstracts of Hon. Treasurer's accounts, 320-323.
Accounts, abstracts of Hon. Treasurer's, 320-323.
Acetic fermentation. 268.
Additions to the Library—
    By donation, 340-345 ; by purchase, 345-348.
Advances in Chemical Industry during the Nineteenth Century, by George T. Beilby, 189-217.
Aerobic organisms, 268.
Africa, trade in Central, 122.
Age Incidence in Zymotic Diseases, by Dr. John Brownlee, 301-310.
Alkali, Act of 1863, 194 ; early demand for, 191 ; industry, periods in the history of, 192.
Allen, H. Stanley, on Experiments in Radio-Activity, 82-96 ; on Physical Apparatus, 176-180.
Ammonia soda process, 199.
Ampère, 11.
Anaerobic organisms, 268.
Anæsthetics, 273.
Anthrax bacillus, 274.
Antiseptic surgery, 270.
Antitoxins, 283.
Apparatus, Physical, notes on, by H. Stanley Allen, 176-180.
Appendix (Articles of Association) 379.
Aqueous Solutions, the Viscosity of, by Dr Charles E. Fawsitt, 171-175.
Arago's experiment, 17.
Architectural Section, office-bearers of the, 337.
Articles of Association, 379.
Aseptic surgery, 272.
Ashley, Prof., on the Fiscal Problem, 219-230.
Assyria, early trade in, 132.
Atlantic Liners, dimensions, etc. of, 249.
Atomic Theory, Dalton's. 97 ; weights, methods of determining, 100, 101.
"Atrato," the, 236, 237,
Auditors appointed, 312.
Avogadro's law, 100.

B.A. and absolute units, 31.
Babylonia, early trade in, 135.
Bacilli of various diseases discovered, 277.
Bacteria and disease, 274.
Bacteria as producers of disease, 282.
Barlow's wheel, 8.
Beetroot Sugar industry, 211.
Beilby, George T., on advances in Chemical Industry during the Nineteenth Century, 189-217.
Becquerel radiation, 83 ; rays, 53.
Biological Section, 337.
Bleaching powder, early manufacture of, 195.
Brownlee, Dr John, on Age Incidence in Zymotic Diseases, 301-310.
Brunel (see "Great Eastern").
Brush, an electro-plating, 178.
"Buenos Ayrean," the, 243.

Cable-signalling, 37, 39.
Cable-laying, history of, 38,
Caird, Dr Robert, on developments in the Means of Communication by Sea, 231-249.
Castner cell, 202 ; Castner process, 197.
Castner, H. Y., 205.
Cavendish, Henry, 2.
Cells, animal and vegetable, 265.
Centenary—Celebrations, account of, 313 ;
,, —Lectures, 1, 97, 189, 231, 263.
"Charlotte Dundas," the, 232.
Chemical combination and viscosity, 174.
Chemical Industry, Advances in, during the Nineteenth Century, by George T. Beilby, 189-217
Chemistry, physical, 113-118.
Chemical Theory, some developments in during the Nineteenth Century, by Prof. Henderson, 97-119.
Choroform, discovery of, 273.
Churches, proper work of, 166.
Coal export, 225.
Cocci, the different, 276.
"Comet," the, (Bell's), 233.
Committee, on Finance, 339 ; on the Library, 339 ; on Papers, 339 ; House, 339 ; on the Science Lecture Trust and the Graham Medal Fund, 339.
Committees appointed by the Council, 339.
Compound engine introduced into ships, 241, 245.
Conductivity, electrical, and viscosity, 174.

Constitution of the Society (see Articles.)
Contact process (see Squire).
Council, Report of, for session 1903-1904, 313-317; Members of, 336.
Convection, electric, 29.
Convict, routine treatment of, 157.
Coulomb, 3.
Crime and bad company, 165.
Criminal and offender, the Treatment of, by Dr James Devon, 150-170.
Cumming's discovery of the neutral point, 29.
Curies, work of the, 53.
Culture media, 275.
Curie, researches of M. and Mme, 85.
Current, action of, on a magnet, 4.
Curves, representative of age distribution of diseases, equations of, 309.
Cyanide process, 206.
Cytology, modern, 265.

Dalton's Atomic Theory, 97.
Davy, Sir Humphrey, 4.
Developments in the Means of Communication by Sea, by Dr Robert Caird, 231-249.
Devon, Dr James, on the Treatment of the Criminal and Offender, 150-170.
Diphtheria (see antitoxin).
Disease, bacteria as producers of, 282; serum treatment of, 284.
Diseases, age distribution of, equations to representative curves, 309; bacilli of various, discovered, 277; Statistics of age incidence in, opp. 308; Zymotic (see Brownlee).
Dissociation, 115.
Drink and committals to prison, 158, 159.
Dulong and Petit's law, 101.
Dynamos, Hopkinson's work on, 42.
,, Edison's, 43.

Economic Science Section, office-bearers of the, 338.
Edison's dynamos, 43.
Education, compulsory in the Highlands 67; in Scotland, Royal Commission on, 176.
Education in the Highlands, Prof. Maclean on, 63-81.
Egypt, early trade in, 130.
Electrical generators, early, 41.
Electrical Science during the Nineteenth Century, Prof. Gray on, 1.
Electrical units, systems of, 35, 36; work and heat, 18.
Electric currents, mathematical theory of, 11.
Electric discharge, theory of, 47, 48.
Electrolysis, theory of, 117.
Electrolytes, viscosity of solutions of, 173.
Electro-magnetic theory of light, 28.
Electrons, 38.
Electro-plating brush, an, 178.
Energy, Poynting's theory of flow of, 52.
Energetics of voltaic circuits, 19.
Etruria, early trade in, 141.
Exchange, *media* of among primitive races, 123.
Exchanges, list of (countries arranged alphabetically), 348-356.
Export, coal, 225; tin plate, 228.
Exports and Progress, 56.
Exports, invisible, 60, 221: visible, 222.
Extraordinary Meetings of the Society, 332, 333.
Fairs (see Markets).
Faraday's researches, 7; on induced currents, 12.
Fawsitt, Dr Charles E., on the Viscosity of Aqueous Solutions, 171 175.
Ferments, 267.
Fiscal Policy, Prof. Smart on the, 55-62.
Fiscal Problem, the, by Prof. Ashley, 219-230.
Finance of the Society, report on the, 317; committee on, 339.
Flacherie (see silkworms).
Flying Machines, the stability of, by W. E. Williams, 181-188.
Franklin, Benjamin, 1.
Free Church Schools in the Highlands, 73.
Froment's electro-magnetic engine, 9.
Fukuzawa, Sampachi, on the Future of Japan, 289-300.
Fund, Graham Medal and Lecture, 322; Science Lecture, 323.
Future of Japan from the Geographical point of view, the, by Sampachi Fukuzawa, 289-300.

Gaelic School Society, 71.
Gaelic tongue, Act for the abolition of, 67.
Gaelic, teaching of, sanctioned by the Education Department, 79, 80.
Galvani, 2.
Galvanometer, Thomson's, 6.
Gauss on Magnetic Measurements, 31.
Gay-Lussac's law of combination, 99.
Gay-Lussac tower, the, 209.
General Assembly Schools in the Highlands, 72.
Generators, early electrical, 41-45.
Geographical and Ethnological Section, office-bearers of the, 338.
Gliders, examples of paths of, 186, 187.
Glover tower, the, 209.
Graham Medal, Rules of Competition for, 311; Fund, 332, 339.
Gray, Prof. Andrew, on the development of Electrical Science, and the Electro-magnetic theory of Light,
Gray, Stephen, 1.
"Great Britain," the, 235.
"Great Eastern," the, 236, 237, 238.
"Great Western," the, 235.
Grünbaum (see serum).

Heat produced by electric current, 19.

Hebrew trading, early, 139.
Henderson, Prof. G. G., on some developments in Chemical Theory during the Nineteenth Century, 97-119.
Hertz, researches of, 49-52.
Highlands, Development of; Education in the, 63-81.
Highlands, Royal grant for reformation of, 71.
Historical and Philological Section, office-bearers of the, 338.
Homes for liberated female prisoners, 155.
Hopkinson's work on dynamos, 42.
Hornblende, 258.
House Committee, 339.
Hydrogen molecule, diameter of, 98.
Hydrophobia, 280.
Huggins, Sir William, letter from, 334.

Icolmkill, Statutes of, 66.
Induction current, Faraday's discovery of, 12.
Immunity, the question of, 281.
Importuning and Prostitution, 160.
Index, 396-400.
Inoculation, preventive, 278.
Invisible exports, 60, 221.
Ionic charges and the electro-magnetic field, 38.
Ionisation, 117.
Ions, and ionization, 201; migration of the, 117.
Iron ships, introduction of, 235.
Isomerism, 108, 110.

Japanese and the sea, 297.
Japan, distribution of population over, 290; dependent on maritime development, 291; increase of population of, 290; its geographical situation, 292; its condition from the geographical point of view, 294; its resources, 296; its recent progress, 299.
Joule's motor, 10.

Kelvin, Lord, on the Peltier effect, 29.
Kelvin's, Lord, work, 28.
Kerr's, Dr John, discoveries, 24, 25.
"King Edward," the, 246.
Knox, John, his influence on Education in Scotland, 65
Koch's work, 275, 276, 277.

Ladies' Association Schools, (Church of Scotland, and Free Church) in the Highlands, 74.
Leblanc's process, 191, 193.
Lenz, law of, 17.
Library, committee on the, 339.
Library Committee, report of, 318.
Light and magnetism, 20.
Light, electro-magnetic theory of, 45-52; plane polarised, 21.
Liners, Atlantic, dismensions, etc., of, 249.
Lines of force theory, 15-17.
Liquids, method of measuring the viscosity of, 171.
Lister, Lord (see antiseptic).
Lothar Meyer and the Periodic Law, 103.

M'Kendrick, Prof., Lecture on Voice Tones, 326.
Maclean, Prof. Magnus, on the Historical Development of Education in the Highlands, 63-81.
Macnair, Peter, on Pseudogaylussite, etc., 250-262.
Malaria, parasite of, 277.
Magnetic action, Faraday's theory of, 15.
Magnetic action of electric current, 10.
Magnetism and light, 20.
Magneto-electric machines, 19.
Manson (see malaria).
Markets and Fairs, Some Observations on Primitive, by Sir James Marwick, 120-149.
Marwick, Sir James, on Some Observations on Primitive and Early Markets and Fairs, 120-149.
Mathematical and Physical Section, office-bearers of the, 338.
Mathematical theory of electric currents, 11.
Maxwell's electro-magnetic theory of light, 28, 45.
Media of exchange among primitive races, 123.
Medical Knowledge, state of, at beginning of Nineteenth Century, 263.
Medical Science, Some Advances in, during the Nineteenth Century, by Prof. Robert Muir, 263-288.
Members of the Society—honorary, 360, corresponding, 361, ordinary, 361-377.
    New:—
        Honorary.
        Huggins, Sir William, 333.
        Mendeléeff, D. Ivanovitsch, 332.
        Ordinary.
        Allan, James A., 328.
        Baird, Allan F., 329.
        Barman, Harry D. D., 330.
        Beckett, Charles E., 313,
        Burr, Robert A., 324.
        Chisholm, John, 324.
        Campbell, Joseph Dawson, 313.
        Cleghorn, Alexander, 330.
        Carswell, Dr. John, 325.
        Douglas, William M., 313.
        Fullarton, Prof. Robert, 313.
        Gray, Albert A, 313.
        Gourlay, Robert, 328.
        Johnston, Michael, 326.
        Kay, Arthur, 327.

Kennedy, Bailie John, 327.
Lamberton, Andrew, 330
M'Ausland, William F., 313.
Mackay, R. C., 313.
M'Kean, Francis, 313.
Mackinnon, William, 328.
Martin, William, 325.
Miller, Robert, 325.
Mitchell, Andrew Acworth, 325.
Moore, Robert Thomas, 330.
Reid, Walter M. N., 335.
Russell James, 330.
Smith, David Baird, 313.
Shand, F. J., 326.
Williams, Principal Alexander Malcolm, 325.
Walker, Hugh, 326.
Young, John Ross, 313.
Membership, report on, 317.
Mendeléeff, D., letter from,
Mendeléeff and the Periodic Law, 103.
Messel (see Squire).
Metchnikoff (see phagocytosis).
Mexico and Peru, early trade in, 141.
Micrococci, 286.
Micro-organisms (invisible) 286.
Middlemen or traders, rise of, 125.
"Mild," steel first used in shipping, 243.
Mineral waters, radio-active gas in, 92.
Minutes of Session, 312-335.
Mitscherlich's method of determining atomic weights, 101.
Molecule, constitution of the, 107.
Molecule of hydrogen, diameter of, 98.
Money, invention of, among tribes of Central America, 124.
Morts-flats (see silkworms).
Mosquito (see malaria).
Muir, Prof. Robert, on some advances in Medical Science during the Nineteenth Century, 263-288.

New Members, 313, 317, 324, 325, 326, 327, 338, 330, 332, 333.
Nickel steel for shipbuilding, 243.
Non-Electrolytes, viscosity of solutions of, 172.
Notes on Physical Apparatus, by H. Stanley Allen, 176-180.

Ocean Steamers, fast, 247.
Oersted, 4
Offenders Act. First, 163.
Offenders, aged, 166 ; habitual, 168.
Office-bearers of the Society, 336-339 ; election of, 318, 319.
Ohm, determination of the, 32, 33.
Ohm's law, 12.
Osmotic pressure, 114.

P. & O. Company, 240.
Papers, committee on, 339.
Parish Schools in Scotland, 67, 68.
Parochial and Burgh Schools, 75.
Parsons, the Hon. Charles (see "Turbinia.")
Pasteur, 266.
Pébrine (see silkworms).
Peltier's discovery, 29.
Petit (see Dulong).
Periodicals on the Library tables, list of, 357-359.
Periodic Law, 103-106.
Peru, early trade in, 141.
Phagocytosis, 281.
Phœnician trade, early, 141.
Physical Apparatus, notes on, by H. Stanley Allen, 176-180.
Physical chemistry, 113-118.
Piston speeds of marine engines, 245.
Poets, Highland, as teachers, 70.
Polarised light, 21
"Potosi," the, 241.
Poynting's theory of energy, 52.
Primitive and Early Markets and Fairs, Sir James Marwick on, 120-149.
Primitive races, trade of, 121.
Prisoners, assistance of liberated, 155 : homes for liberated female, 155 ; routine undergone by, 153 ; work for, 154.
Prison, committals to, and drink, 158, 159 ; not a reformatory, 152.
Prison Commissioners, Reports of, 158.
Probability curve, application to disease statistics, 301-310.
Propeller Screw, introduction of, 239.
Prostitutes, alleged blackmailing of, 161-163.
Prostitution and Importuning, 160.
Pseudogaylussite, and some other minerals, by Peter Macnair, 250-262.
Pseudogaylussite, analyses of, 252, 253.
Pseudomorphs. 257, 260.
Punishment and the repression of crime, 152.
Punishment should vary as the *criminal* not the *crime*, 164, 167.

"Queen Alexandra," the, 246.

Radio-activity, 54 : H. Stanley Allen on, 82-96 ; kinds of, 86 ; Lord Blythswood and Mr. Allen's experiments on, 92.
Radio-active gas in mineral waters, 92.
Radium, production from pitch-blende, 85 ; list of properties of, 86-90 ; influence on spark length, 91.
Radium radiation and contact electricity, 92.
Rayleigh, Lord, determination of the ohm, 33.
Reaction velocity and viscosity, 174.
Report of Council, 313-317 ; of Library Committee, 318.
Röntgen Rays, 53.
Ross, Major, (see malaria).
Roux and Yersin (see toxins).
Royal Society, address from the, 315.

"Royal William," the, 234.
Rowland's discovery, 37.

Sanitary and Social Economy Section, office-bearers of the, 337.
Scarlet fever, age incidence in, 307.
"Schlempe," 213.
School buildings in the Highlands, 77.
School rate in the Highlands, 78.
Schwann (see cytology).
Science Lecture Trust, 323, 339.
Science Lectures Fund, 323.
Scott Russell (see "Great Eastern").
Screw propeller, introduction of, 239.
Seebeck's discovery, 28.
Self-induction, 18.
Serum diagnosis, 285.
Serum treatment of disease, 284.
Ships, comparative length of iron and wooden, 236.
Siberia, trade of, 145.
Siemens, Sir W., on electric lighting, 40.
Silkworms, Pasteur on diseases of, 273.
Simpson (see chloroform).
Siphon-recorder, 7.
"Sirius," the, 235.
Smallpox, age incidence in, 306.
Smart, Prof. W., on the Fiscal Policy, 55-62.
Soda ash process, 198.
Solution, viscosity of several substances in, 173.
Solution, theory of, 113.
Solutions, the Viscosity of Aqueous, by Dr Charles E. Fawsitt, 171-175.
Solvay process, 195.
Some advances in Medical Science during the Nineteenth Century, by Prof. Robert Muir, 263-288.
"Song-Schools" in the Highlands, 65.
S.P.C.K., origin of, influence of Education in Scotland, 69, 70, 72, 77.
Squire and Messel's contact process, 210.
Stability of Flying Machines, by W. E. Williams, 181-188.
Staining agents (in bacteriology), 276.
Statistics, shipping for 1903, 242.
Steamers, fast ocean, 247.
Steam pressures in marine boilers, 245.
Stereo-chemistry, 111.
Subscription and other schools in the Highlands, 75.
Suez Canal, effect of, on marine plant, 241.
Sulphuric acid, manufacture of, 208.
Surface condensation in marine engines, 244.
Surgery, antiseptic, 270; aseptic, 272.

Tait, Prof., on the thermo-electric diagram, 30.
Telegraphy, 6.
Telephones, 45.
Tetanus toxin, 283.
Thermo-electric diagram, 30.
Thermo-electricity, 28.
"Thermopylæ," the, 241.
Thomson's galvanometer, 6.
Thomson's, Sir William, work, 28.
Tin plate industry, 228.
Tonnage, comparative, of iron and wooden ships, 236.
Tower, the Gay-Lussac, 209; the Glover, 209.
Toxins, 282.
Trade, early, in Assyria, 132; in Babylonia, 135; in Egypt, 130; in Etruria, 140; in Mexico and Peru, 141; routes, 129. Trade, of primitive races, 121; of Siberia, 145; in Central Africa, 122.
Traders, rise of, 125.
Trading, early methods still in operation, 126; early Hebrew, 139.
Transformers, 43, 44.
Treatment of offenders, suggestions as to the, 168-170.
Treatment of the Criminal and Offender, by Dr James Devon, 150-170.
Tubercle bacillus discovered by Koch, 276.
Turbine, the steam, 246.
"Turbinia," the, 246.
Twin screw, 244.

Vaccination, 279.
Valency of elements, 102.
Velocities, composition of, an apparatus for illustrating, 176.
Viscosity, and chemical combination, 174; and electric conductivity, 174; and reaction velocity, 174; of aqueous solutions, 171-175; of liquids, method of measuring the, 171; of several substances in solution, 173.
Visible exports,222.
Voice Tones, lecture on, 326.
Volta, 2.
Voltaic cell, theory of, 2.

Water, decomposition of, 4.
Waves, electric, 49-52.
Wealth of nomad races, constituents of, 128.
Whooping cough, age incidence in, 305.
Widal (see serum).
Williams, W. E., on the stability of Flying Machines, 186-188.
"Windsor Castle," the, 243.
Women, education of, in the Highlands, 66.
Woolsorters' disease (see anthrax), 275.

Yersin and Roux (see toxins).

Zymotic diseases (see Brownlee).

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